THE UNIVERSITY OF MICHIGAN
APR 28 1961
LIBRARY

Transactions

of the

Illinois State Academy of Science

Volume 53
Nos. 3 and 4
1960

Springfield, Illinois

TRANSACTIONS of the ILLINOIS STATE ACADEMY of SCIENCE

EDITORIAL BOARD:

PAUL C. SILVA, University of Illinois, Editor and Chairman

GEORGE E. EKBLAW, State Geological Survey

F. O. GREEN, Wheaton College

REECE JONES, Western Illinois University

FRANCIS KRUIDENIER, University of Illinois

JOHN MCGREGOR, University of Illinois

MILTON THOMPSON, Illinois State Museum

The current *Transactions* may be obtained by payment of annual dues.

Previous volumes may be obtained by addressing Walter B. Welch, Southern Illinois University, Carbondale.

Exchanges may be arranged by addressing Thorne Deuel, Illinois State Museum, Springfield.

(27135—12-60)

14

A

VO

TRANSACTIONS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 53 - 1960 Nos. 3 and 4

ILLINOIS STATE ACADEMY OF SCIENCE
AFFILIATED WITH THE
ILLINOIS STATE MUSEUM DIVISION
SPRINGFIELD, ILLINOIS

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS
WILLIAM G. STRATTON, *Governor*

APRIL 10, 1961

CONTENTS

The influence of irrigation upon growth and yield of strawberries. By Roy K. Simons 93

Biological availability to the rat of iron and copper from various compounds. By A. H. Nesbit and W. P. Elmslie 101

Enhancement of the nutritional value of cereals through germination. By Albert A. Dietz 106

Spectrophotometry of litmus and related indicators. By W. N. Moulton, B. J. Wilson, and C. H. Staff 115

The Pilot Shale, the West Range Limestone, and the Devonian-Mississippian Boundary in Eastern Nevada. By R. L. Langenheim, Jr. 122

Shoot apices in two hybrid junipers. By Margaret Kaeiser 132

Unusual coat colors in some wild American carnivores. By Donald F. Hoffmeister 141

A concept concerning a set with a binary composition law. By A. A. Mullin 144

Severe summer hailstorms in Illinois during 1915-50. By Stanley A. Changnon, Jr. 146

Stratigraphic aspects of the Caseyville group in the vicinity of Pomona, Jackson County, Illinois. By George A. Desborough 157

Progressivism in Illinois communities as measured by library services. By Robert W. Janes 166

Itapací, Brazil: rapid growth of a frontier town. By Robert L. Carmin 173

THE INFLUENCE OF IRRIGATION UPON GROWTH AND YIELD OF STRAWBERRIES

ROY K. SIMONS
University of Illinois, Urbana

Responses of two varieties of strawberries growing under two levels of soil moisture were recorded for the growing seasons of 1956, 1957, 1958 and 1959 at the University of Illinois Agricultural Experiment Station, Urbana. Substantially virus-free plants of Howard 17 (Premier) and Vermilion strawberries were planted in the spring of 1955 to determine the effects of varied soil moisture levels upon yield and quality of the fruit under midwest growing conditions. Varietal responses, total yield, harvest periods, weight per berry, total number of berries per harvest, soluble solids and pH of the juice have been reported previously (Simons, 1958). The yield data compiled for harvest seasons of 1956, 1957, 1958 and 1959 were analyzed statistically by the methods of analysis of variance with all treatment comparisons made on an individual degree of freedom basis.

Soil Moisture Utilization by Strawberries. Soil samples were collected from the rows and row middles of each variety at the 1-3 and 6-8 inch depths for soil moisture evaluation by the gravimetric method. The irrigated plots were compared with the non-irrigated plots with a total of three replications for each sample observed. These plots were selected from the original planting that consisted of randomized complete blocks, with six replications intended to be low, medium and high in moisture levels for each variety. However, as a result of the amount and frequency of natural rainfall, the moisture levels were essentially non-irrigated and irrigated.

Additional water was applied to the irrigated plots of strawberries for five growing seasons when the upper 6-8 inches of the soil profile was below field capacity in moisture content (Table 1).

Table 1 shows such frequent applications of water that rainfall alone would have been insufficient for successful strawberry production. Soil moisture records at the two depths were similar for both varieties in each year. In some instances all the rain fell at one time and proper utilization of moisture by the plant was not possible. This is recorded in Figure 1 when rainfall was infrequent throughout the 1957 growing season. Response of berries to sufficient and insufficient moisture levels during the critical period of fruit bud formation in August, September and October was particularly evident in the foliage and in fruit production the following spring. The increase in yield for Vermilion in 1959 is attributed to the two applications of water in September and October 1958.

Figures 1, 2 and 3 show the rainfall and the soil moisture levels for irrigated and non-irrigated Vermilion plots at the 6-8 inch depths in the row during the 1957, 1958 and 1959 growing seasons. Shallow depths of 1-3 inches produced rapid fluctuations, but significantly higher

TABLE 1.—Amount of water applied to the irrigated plots of strawberries for five growing seasons.

Year	Amount of water applied (acre inches)	
1955	July 2	1.46
	Aug. 19	1.63
	Aug. 24-26	1.05
	Sept. 1-2	.94
	Sept. 6-9	.83
	Sept. 17	.97
1956	May 26	1.55
	June 6	1.08
	June 9	1.58
	June 13	.55
	July 2	.64
	Sept. 14	.86
	Oct. 12	1.04
1957	May 18	2.44
	May 26	2.25
	May 29	1.58
	June 26	1.11
	July 12	1.21
	Aug. 1	1.03
	Aug. 2	1.23
	Aug. 9	1.42
	Aug. 16	1.90
	Aug. 23	1.80
	Sept. 6	.87
	Sept. 17	1.56
1958	Sept. 12	1.50
	Oct. 22	1.61
1959	May 7	1.96
	June 5	1.77
	June 19	1.98
	June 26	1.60
	June 29	1.53
	July 6	3.21
	July 16	2.41
	July 23	2.98
	Aug. 7	3.14
	Sept. 9	2.03

TABLE 2.—Yield (quarts/acre) of Howard Premier and Vermilion strawberries, 1956, 1957, 1958 and 1959, as affected by irrigation.

Year	Variety	Non-irrigated	Irrigated	% increase
1956	Howard Premier	7,230	8,885	22.8
	Vermilion	7,492	10,192	26.7
1957	Howard Premier	5,706	6,511	14.1
	Vermilion	6,141	7,644	24.5
1958	Howard Premier	5,818	6,378	9.6
	Vermilion	5,538	8,167	47.4
1959	Howard Premier	4,556	4,686	2.8
	Vermilion	6,639	7,518	13.2

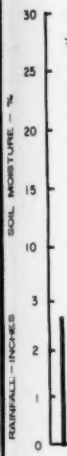


Fig.
vs. non-

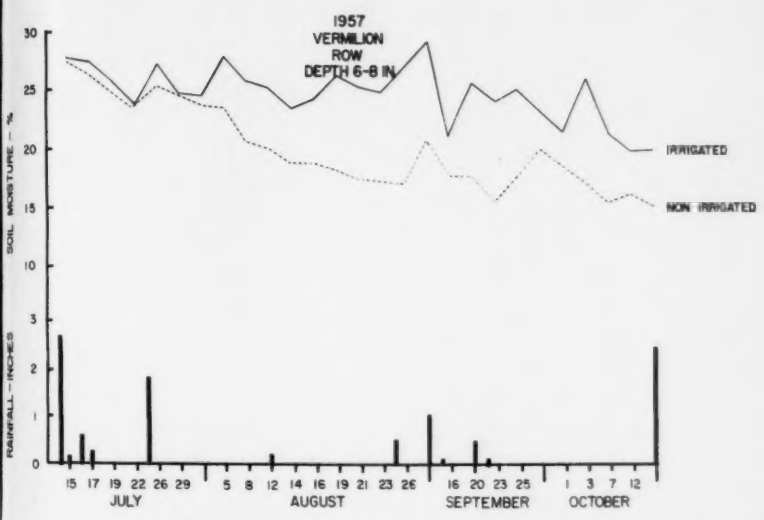


Fig. 1.—Soil moisture in the row at 6-8 inch depth for Vermilion—irrigated vs. non-irrigated, 1957.

moisture content was retained in the irrigated plots. However, when the soil moisture at the 1-3 inch depth was compared with that at the 6-8 inch depth, there was a general tendency for the 6-8 inch depth to have a higher soil moisture content throughout the growing season.

Since the Vermilion berry responded significantly to additional water, the levels of natural soil moisture supply would have to be classified as insufficient for plant performance. For example, a 47.4% increase in yield was accomplished in 1957 by adding irrigation water. The plants that were not irrigated did not produce sufficient runners for commercial production of strawberries.

During the 1959 harvest season, it was observed that Vermilion increased 13.2% when water was applied and Howard Premier by only 2.8% (Table 2). The soil moisture trends for the 1958 season show that Vermilion was in the deficit moisture range during early September through October at a critical time when fruit buds were developing. The increased yield of Vermilion from the irrigated plots in 1959 was an indication of this deficiency.

The 1959 data show the effects of adding supplemental water to these strawberry plots (Fig. 3). The soil moisture was in the deficit range from early June throughout the remainder of the growing season. Field observations of these plants show that they were low in vigor; little or no runner production was made after renovation in June.

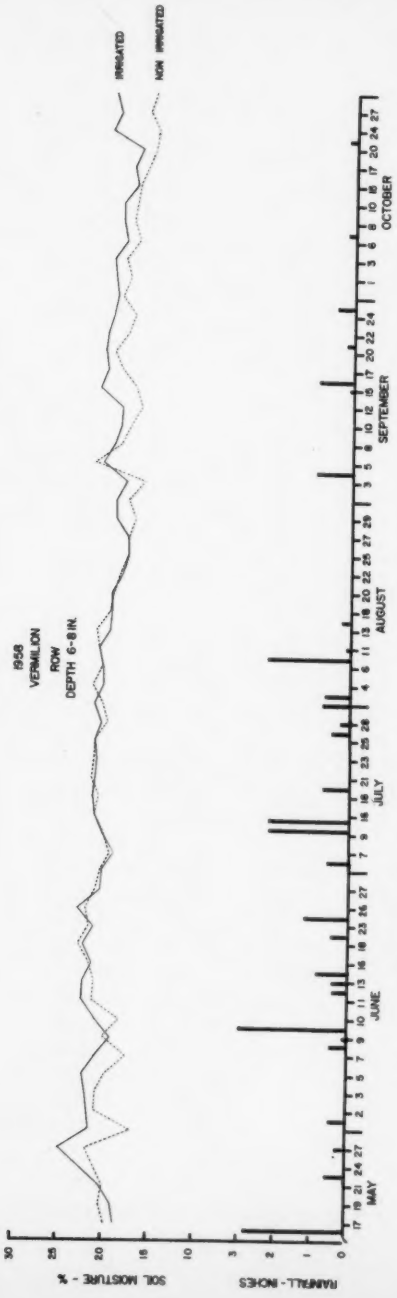


Fig. 2.—Soil moisture in the row at 6-8 inch depth for Vermilion—irrigated vs. non-irrigated, 1958.

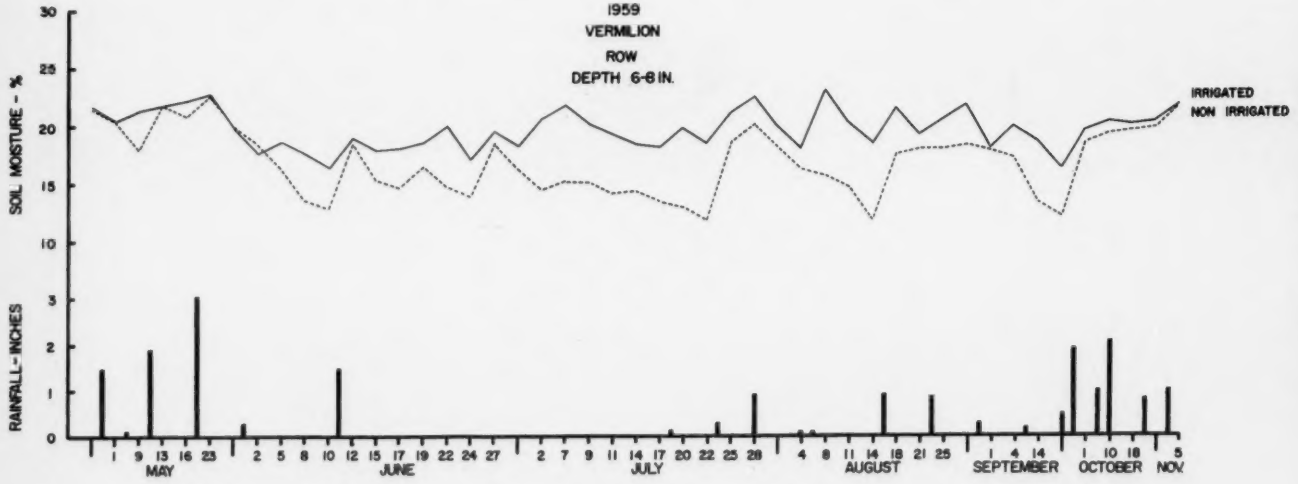


Fig. 3.—Soil moisture in the row at 6-8 inch depth for Vermilion—irrigated vs. non-irrigated, 1959.

TABLE 3.—Average berry weight (grams) of Howard Premier and Vermilion strawberries, 1956, 1957, 1958 and 1959, as affected by supplemental irrigation.

Variety	Non-irrigated				Irrigated			
	1956	1957	1958	1959	1956	1957	1958	1959
Howard Premier	6.43	5.90	5.75	5.45	6.04	5.56	6.96	5.42
Vermilion	6.95	6.86	7.83	7.56	6.61	6.83	8.90	7.37

TABLE 4.—Average berry weight (grams) of Howard Premier and Vermilion strawberries for three harvest seasons of 1957[1], 1958[2], and 1959[3].

Period	Variety					
	Howard Premier			Vermilion		
	1957	1958	1959	1957	1958	1959
1	7.8	9.0	8.4	9.7	12.9	12.6
2	5.7	6.6	6.0	6.7	8.0	7.7
3	3.5	3.7	3.0	4.2	4.7	3.5

[1] Period 1. Pickings 1 & 2. Period 2. Pickings 3, 4 & 5. Period 3. Pickings 6 & 7.
[2] Period 1. Pickings 1 & 2. Period 2. Pickings 3, 4, 5, & 6. Period 3. Pickings 7 & 8.
[3] Period 1. Pickings 1 & 2. Period 2. Pickings 3 & 4. Period 3. Pickings 5 & 6.

Yield Response for Four Harvest Seasons. Data from the four experimental years showed significant increases in total yield for the berry plots that received supplemental moisture. Total yield for the harvest seasons of 1956, 1957, 1958 and 1959 is shown in Table 2.

The yield for 1956 and 1957 showed a marked response to the application of supplemental water. A highly significant response was noted in both varieties between the non-irrigated and irrigated plots in 1956 and 1957. For 1958, Vermilion responded with a 47.4% increase when additional water was applied. Again, a significantly greater response to irrigation was recorded by Vermilion than by Howard Premier in the 1959 harvest season. It is evident that each variety responded significantly to irrigation, but greater increases were noted for Vermilion. The interaction between irrigation and varieties was statistically significant.

Total weight of fruit harvested for the four harvest years was significantly greater from plants where supplemental irrigation had been applied during the preceding grow-

ing season. Distinct differences were recorded between the two varieties, Vermilion significantly yielding more than Howard Premier in all the treatments.

Average berry weight is of considerable importance in successful strawberry production. The data in Table 3 show the differences between Howard Premier and Vermilion varieties of berries for the harvest seasons of 1956, 1957, 1958 and 1959.

Irrigation did not have any effect upon size of the berries for the 1956 and 1957 harvest seasons but there was a response for 1958. This may be explained by the lack of water in August, September and early October of the preceding year at the time of fruit bud formation. This is a carry-over effect of the additional water that was applied during October 1957 when severe drought conditions occurred. The contributing factor for increased yields in response to irrigation was the greater fruiting potential as a result of an increased number of fruit buds following application of additional water the preceding year.

Definite differences in berry size are recorded between these two varieties. Vermilion produced the largest berry under both conditions each year. Comparisons of the two varieties during the three picking periods for 1957, 1958 and 1959 are shown in Table 4.

The data in Table 4 show that the Vermilion variety maintained larger berries than Howard Premier throughout the harvest periods during the three years they were studied. Less effort was expended in the harvesting and a higher price could be expected in marketing the fruit. This shows how important it is to choose a variety that will maintain berry size throughout the harvest season. Berry size for period 3 as recorded in Table 4 is not commercially feasible as the berries are too small for a profitable return.

The number of berries produced is not indicative of the size of the yield. Under desirable moisture conditions (the irrigated plots), Howard Premier produced the most berries for 1956 and 1957 but did not equal Vermilion in berry size or in number of quarts. However, for 1958, Vermilion produced more berries as well as larger berries and the greater number of quarts.

Summary

Howard 17 (Premier) and Vermilion strawberries were studied for four harvest seasons in order to determine the effects of varied soil moisture levels upon yield and quality of the fruit. Responses for each variety were recorded, including total yield, harvest periods, weight per berry and total number of berries per harvest.

Rainfall was too infrequent for successful strawberry production. Supplemental moisture applied during critical periods of fruit bud formation resulted in significant yield increases. Soil moisture at the 6-8 inch depth was greater and persisted longer for more effective plant growth than relying on the moisture content at the 1-3 inch depth.

Both varieties of strawberries produced significantly higher yields when irrigated. The irrigated plots produced berries of greater size. Yields were greater for Vermilion

than for Howard Premier. When supplemental moisture was applied at necessary intervals, the Vermilion berry produced good commercial yields and the berries were larger than Howard Premier throughout the harvest season.

Literature Cited

Simons, Roy K. 1958. Response of Howard Premier and Vermilion varieties of strawberries to supplemental irrigation. Proc. Amer. Soc. Hort. Sci., 71: 216-223.

Manuscript received April 28, 1960.

BIOLOGICAL AVAILABILITY TO THE RAT OF IRON AND COPPER FROM VARIOUS COMPOUNDS

A. H. NESBIT and W. P. ELMSLIE
Moorman Manufacturing Company, Quincy

Introduction

Trace minerals for livestock feeding have become an accepted part of modern feeds. Availability of these nutrients to the animal from various sources has been studied in our laboratory for many years. Elmslie *et al.* (1942) published on the availability of manganese, cobalt and copper in new sources of these mineral elements.

Among the various problems facing the feed nutritionist is the stability of certain fat soluble vitamins, particularly vitamins A and D. It has been well established by a number of investigators that the stability of these vitamins is affected by the trace elements added to the diet.

Fritz *et al.* (1942) found mineral mixtures to be destructive to vitamin D. Halverson and Hart (1950) demonstrated a rapid destruction of vitamin A induced by adding iron, copper, cobalt and manganese to an unsealed white corn sample containing added cod liver oil. Destruction was largely prevented when the minerals were covered by a gelatin mixture. Halverson and Hendrick (1955) demonstrated an even greater loss of vitamin A when the trace minerals were added at higher levels as in a feed concentrate. Kamstra *et al.* (1953) found that carotene stability was also affected by trace minerals.

In these cases cited, the trace minerals were added in the form of either the sulfate or the chloride which are water-soluble. In an attempt to prevent this destruction, some commercial manufacturers of trace mineral premixes have utilized the water-insoluble forms. In this series of experiments we attempted to measure the relative biological availability of some of the water-insoluble forms of trace elements claimed to improve vitamin stability.

Experimental Procedure—Iron Availability Studies

Two experiments using albino rats were conducted to study the relative availability of iron from ferrous carbonate, ferrous sulphate and metallic iron. In both trials essentially the same experimental procedure was followed. Pregnant females were placed in clean, freshly painted litter cages shortly before parturition. The cages were equipped with a wire floor and a board covering one-half of the wire with cotton for bedding.

Milk was used as the basic ration for the anemia studies, since it is almost devoid of iron, which is essential to the production of the hemoglobin molecule. Only fresh milk was offered to the female in the cage in addition to water. Therefore, once a day she was removed to a separate cage for dry food. After being allowed to eat for approximately one hour, she was brushed thoroughly to remove excess dry feed and returned to the litter cage.

At 21 days the young were weaned and placed in individual cages. Each

rat was fed daily 1 g. of mineralized dried milk containing 0.05 mg. of copper and 0.04 mg. of manganese. After the dried milk supplement was consumed, fresh cow's milk was supplied *ad lib*. Hemoglobin and red blood cell counts were obtained according to standard procedures at weekly intervals. Blood samples were obtained from the tail of the rat by splitting the vein with a sharp scalpel. Blood flow could be easily stopped by pressure placed over the wound. After three weeks on the milk diet the rats were sufficiently anemic to be assigned the various treatment procedures for repletion feeding. The animals were distributed among the various treatments according to litter, weight, sex and blood picture. Supplementary iron was supplied in the mineralized dried milk supplement at the rate of 0.2 mg. of iron per rat per day.

Results—Iron Availability Studies

In Experiment 614 ferrous sulphate and ferrous carbonate were compared for hemoglobin and red blood cell regeneration in the rat. Iron deficiency anemia is described as microcytic hypochromic in nature. The normal rat three weeks post-weaning should have a hemoglobin level in the neighborhood of 13 g. per 100 cc of blood and a red blood cell count of from 8 to 10 million cells per cubic millimeter. At three weeks post-weaning these rats exhibited a typical blood picture of iron deficiency anemia. After 12 days of repletion feeding at the rate of 0.2 mg. of iron per rat per day, the rats receiving their iron in the form of ferrous sulphate increased hemoglobin 129% over their initial level while the rats supplemented with ferrous carbonate increased only 26%. The increases in red blood cells were in the same direction (Table 1).

In Experiment 716 ferrous sulphate, ferrous carbonate and finely divided metallic iron were compared. Again ferrous sulphate increased the hemoglobin 121% while ferrous carbonate increased it only 35% and metallic iron 67% in two weeks of repletion feeding. The red blood cells follow the same pattern except that the metallic iron in this case was equal to ferrous sulphate (Table 2).

Experimental Procedure—Copper Availability Studies

In the copper work a different technique was employed instead of the direct approach used in previous studies (Elmslie *et al.*, 1942) which had been based upon the requirement of the rat. The present method involved high level supplementation, with storage of copper in the liver as the criterion of availability. Boyden *et al.* (1938) observed considerable liver storage of copper when rats were fed a diet containing 500 ppm of copper with no substantial reduction in food consumption. This finding served as a guide in the design of our experiment.

The regular colony ration was used as the basal diet. This diet was formulated from natural feed ingredients and contained some copper from these sources. To this basal ration supplementary levels of copper were added. Copper sulphate (25½% Cu) to furnish 125, 250 and 500 mg. of copper per kilogram of

TABLE 1.—Experiment 614. Ferrous sulphate vs. ferrous carbonate for hemoglobin and red blood cell regeneration in the iron deficient rat.

	Ferrous Sulphate	Ferrous Carbonate
Number of rats	6	6
Blood picture, 3 weeks depletion post-weaning		
Ave. red blood cells/mm.^{3}	4,510,000	5,090,000
Ave. hemoglobin g./100 cc blood	4.25	4.24
Blood picture, 12 days repletion (0.2 mg Fe/rat/day)		
Ave. red blood cells/mm.^{3}	8,070,000	6,000,000
% Increase	78.9	17.8
Ave. hemoglobin g./100 cc blood	9.74	5.35
% Increase	129.1	26.1

TABLE 2.—Experiment 716. Comparison of ferrous sulphate, ferrous carbonate and metallic iron for hemoglobin and red blood cell regeneration in the iron deficient rat.

	Ferrous Sulphate	Ferrous** Carbonate	Metallic Iron
Number of Rats	6	5*	6
Blood picture, 3 weeks depletion post-weaning			
Ave. red blood cells/mm.^{3}	4,320,000	4,000,000	4,060,000
Ave. hemoglobin g./100 cc blood	5.96	6.23	5.87
Blood picture 2 weeks repletion (0.2 mg Fe/rat/day)			
Ave. red blood cells/mm.^{3}	6,540,000	5,180,000	6,180,000
% Increase	51.3	29.5	52.2
Ave. hemoglobin g./100 cc blood	13.18	8.43	9.84
% Increase	121.1	35.3	67.6

* One animal developed pneumonia, removed from test.
** Different source of supply from Experiment 614.

diet served as the control. Copper oxide (83.7% Cu), copper pyrophosphate (16.2% Cu) and copper concentrate (74.1% Cu) were added to furnish copper levels of 250 and 500 mg. per kilogram of diet. After four weeks of feeding, the animals were sacrificed and the liver removed, weighed and analyzed for copper.

RESULTS—COPPER AVAILABILITY STUDIES

In the copper studies, Experiment 732, liver copper levels ranged from 75 μg. per liver on the basal diet, which may be considered a "normal" ration, to over 1500 μg. per liver at the 500 mg. of copper level furnished by copper sulphate. At the 500 mg. level from copper pyrophosphate, copper oxide and the copper concentrate, the livers contained on the average only 400, 180 and 260 μg. of copper, respectively (Table 3). It is obvious that these compounds are much less available than copper sulphate as measured by the liver storage technique.

Since there was some variation in the actual copper intakes, availability was calculated on the basis of intake rather than the concentration in the diet. Using the graphical method of estimation and assuming copper sulphate to be 100%

TABLE 3.—Experiment 732. Liver copper levels in the rat fed copper from various sources and relative availability of copper.

	Copper Added (mg./kg. diet)	Ave. Total Gain Per Rat (g.)	Suppl. Copper Intake/Rat (mg.)	*Total Copper Per Liver (μg.)	% Availability
Basal Control.....	None	118.7	None	74.5	.....
Copper sulphate.....	125	113.5	44.0	215.7	100
Copper sulphate.....	250	120.7	95.5	304.0	.....
Copper sulphate.....	500	118.7	178.0	1,517.7	.....
Copper pyrophosphate.	250	117.0	94.5	221.5	49
Copper pyrophosphate.	500	121.0	191.0	404.0	.....
Copper oxide.....	250	113.5	95.6	111.5	27
Copper oxide.....	500	124.2	204.0	181.7	.....
Copper concentrate....	250	127.0	120.0	185.7	34
Copper concentrate....	500	126.0	204.0	261.0	.....

* Average of 4 rats on each treatment. Livers were analyzed individually.

available, copper pyrophosphate appears to be 49%, copper oxide 27% and the copper concentrate 34% available under the conditions of this experiment. As in most biological tests, considerable variation and uncertainties exist; therefore, the availability percentages assigned serve merely as a relative ranking with respect to copper sulphate, rather than as exact percentages.

Discussion

Under our conditions with the particular basal diets used, the carbonate form of iron is relatively unavailable for the iron-deficient rat. For maximum rate of hemoglobin and red blood cell regeneration in the rat it appears that ferrous sulphate, a water-soluble form of iron, is more efficient than the other sources of iron used in this study. This may not necessarily be true for other species, such as poultry.

It is quite possible that copper availability may be influenced by the kind of diet used or the species of animals concerned. Unpublished work from our laboratory indicates that poultry may utilize copper oxide more efficiently than does the rat. Under certain conditions in practical livestock feeding water-insoluble sources of copper may be as satisfactory or more so than the readily soluble salts. Becker *et al.* (1953) reported that 5 g. of copper sulphate fed daily to a 500 lb. steer was toxic with death occurring after 122 days of feeding. An equivalent amount of copper from copper oxide was fed to two 500 lb. steers daily for 15 months without observing toxicity. Our data suggest that the relative toxicity of copper oxide and copper

sulphate may be due to their relative availability of copper but does not exclude the possibility that the rate at which copper may be absorbed into the body is also a factor.

Summary

1. Based on hemoglobin and red blood cell regeneration in the anemic rat, ferrous carbonate was relatively unavailable when compared to ferrous sulphate. Metallic iron was intermediate between ferrous carbonate and ferrous sulphate in its ability to regenerate hemoglobin and red blood cells.

2. Using liver copper storage in the rat as the criterion, copper oxide copper concentrate and copper pyrophosphate were approximately one-fourth, one-third and one-half as available, respectively, as was copper sulphate.

Literature Cited

Becker, R. B., P. T. Dix Arnold, W. G. Kirk, George K. Davis and R. W. Kidder. 1953. Minerals for dairy and beef cattle. Florida Exper. Sta. Bull. No. 513. 51 pp.

Boyden, Ruth, V. R. Potter and C. A. Elvehjem. 1938. Effect of feeding high levels of copper to albino rats. Jour. Nutrit., 15: 397-402.

Elmslie, W. P., W. R. Bunting, R. A. Sturdy and Paul R. Cutter. 1942. New Sources of mineral elements in animal nutrition. Trans. Ill. St. Acad. Sci., 35: 95-96.

Fritz, James C., Wallace F. Archer, and Donald K. Barker. 1942. Observations on the stability of vitamin D. Poultry Sci., 21: 361-369.

Halverson, A. W. and E. B. Hart. 1950. Factors affecting the stability of vitamin A from cod liver oil in cereal feeds. Jour. Nutrit., 40: 415-427.

Halverson, A. W. and C. M. Hendrick. 1955. Effect of trace minerals and other dietary ingredients upon vitamin A stability in stored poultry diets. Poultry Sci., 34: 355-360.

Kamstra, L. D., A. W. Halverson and A. L. Moxon. 1953. Effect of trace minerals and other dietary ingredients upon the carotene stability in stored poultry diets. Poultry Sci., 32: 352-356.

Manuscript received April 28, 1960.

ENHANCEMENT OF THE NUTRITIONAL VALUE OF CEREALS THROUGH GERMINATION

ALBERT A. DIETZ
1618 54th Street, La Grange

The limitations of cereal diets have been known and discussed for many years, and the relative nutritional values of various cereals have been reported many times. Jones, Caldwell, and Widness (1948) reviewed the inconsistencies in the early reports, and in their work found that oats, rice, and rye were superior to the other cereals fed at the same protein levels. Their suggested diets, as well as those used by most workers studying the nutritional properties of cereals, were supplemented with minerals, vitamins, and fats. Thus the relative value of the grains was partly dependent upon the supplement used, and when the diets were sufficiently supplemented to give normal growth, differences in the nutritional value of the cereals could not be seen. Germinated cereals have been used to supplement diets, and reports of their value range from very optimistic (Raybaud, 1929) to those that find them to be of no value (Leitch, 1939). I found no report which compared the unsupplemented germinated cereal directly with the ungerminated. The work reported in the present paper used diets consisting entirely of a single germinated or ungerminated cereal and distilled water. The data show the overall changes in the nutritional properties resulting from germination.

Methods

Germination. The germination was carried out on an industrial scale. The cereals were steeped in tap water for 12-14 hours, with or without the addition of lime. They were then placed on wire shelves and a continuous stream of air forced through the grain. The germination was in the dark for 3-6 days, depending upon the cereal, until the sprouts were about 3 times the length of the seeds. During the germination, the grain was kept moist and turned once daily. At the end of the germination, the product was dried at room temperature in a current of forced air and ground in a hammer mill. Adequate samples of the ungerminated grain were ground for the control diets. The protein was calculated from the nitrogen content as determined by Kjeldahl analysis times 6.25.

Feeding Experiments. Wistar rats were raised on the stock diet of Bills *et al.* (1931). The young were put on the experimental diets at weaning or several weeks after weaning. The results were most uniform when the initial weight of the rats was 50-75 g. For a given experiment, one or more litters was divided, half receiving the ungerminated and half the germinated cereal. The rats were kept in false-bottom cages and received the cereal and distilled water *ad libitum*. They were weighed at weekly intervals, and food consumption records were kept. In all cases, the germinated cereal was from the same source as the ungerminiated with which it was compared.

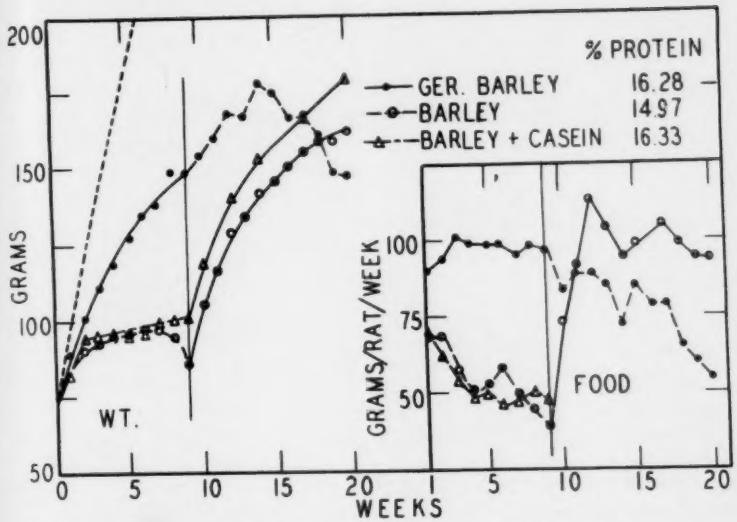


Fig. 1.—Growth and food consumption of rats on diets of barley, germinated barley, and barley supplemented with casein to give a protein content equivalent to that of germinated barley. The values are the averages of four male rats. The symbols represent each group of rats and their diets for the first nine weeks, at which time the diets were reversed. The solid and broken lines represent the germinated barley and barley, respectively. The short dashes represent growth on the stock diet.

Results

Barley. In an initial experiment, the average weight gain of 14 rats receiving only barley (15.13% protein) was 20.3 g. in 10 weeks, whereas 14 rats fed germinated barley (16.20% protein) gained an average of 60.4 g. in the same interval. Half of the rats receiving barley died in the tenth week, and one survived 25 weeks. Five of the animals fed germinated barley were still alive in the 38th week when the experiment was terminated.

The higher protein content of the germinated cereal, according to Bartlett (1917), is due to the loss of carbohydrate during germination. To test whether the higher protein content of the germinated cereal was responsible for the more rapid growth, barley was supplemented with commercial casein to increase its protein content to that of the germinated grain. The results of the feeding and the analyses of the diets are given in Figure 1. For nine weeks, three groups of four rats each received barley, barley-casein, or germinated barley diets. At the end of this period, those receiving the germinated barley had gained an average of 80 g., whereas those on the barley or barley-casein

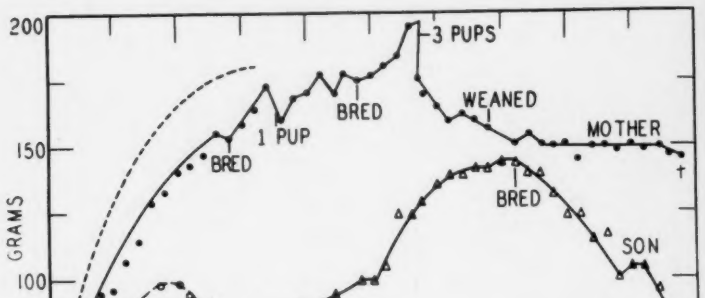


Fig. 2.—Growth and longevity of rats receiving barley and germinated barley. The protein analysis of the diets was 15.08 and 15.50%, respectively. The triangles represent the second generation on germinated barley. The short dashes represent growth on the stock diet.

diets gained an average maximum of 30 and 35 g., respectively. At nine weeks, the four rats fed the casein-supplemented barley showed a slight but not significant beneficial effect of the casein. At this time, two of the rats receiving barley died. The diets were reversed at the end of nine weeks so that the rats that had received the germinated barley were then fed barley and those on the other two diets then received the germinated cereal. In all cases, the rats grew, but after six weeks on the new diets, the rats now receiving barley began to lose weight. The experiment was terminated in the 20th week when two of the rats receiving barley died. Thus, the total protein is not the determining factor in the enhancement of the value of the cereal through germination.

A study of the food consumption on the three diets (Fig. 1) showed that the rats ate considerably more of the germinated barley at a rather constant rate throughout the experiment. The food consumption of the rats on the barley or barley-casein diets fell almost continuously.

As already noted, the animals fed germinated barley not only grew more rapidly but they survived longer than those eating the ungerminated cereal. Although most experiments were terminated before the animals on the germinated barley died, in eight cases, rats survived for over one year with germinated barley as the sole nutrient, one as

long as 76 weeks. Ten female rats that had been on germinated barley for more than 10 weeks were bred with males from the stock colony. Attempts were made to breed four of them three times. In three cases, litters were cast, but only one mother was able to wean her young. The cycle of the mother and her pups is shown in Figure 2. The mother had received only germinated barley from the time she was a month old. She was bred in the 14th and 24th week on the diet. With the first breeding, one pup was born but it died the next day. As a result of the second breeding, three pups were cast, but only two survived until weaning. They were weaned at the age of 37 days when they weighed 37 and 21 g. (normal weight at this age is 65 g.). The diet of germinated barley was continued. The smaller of the young died during the second week after weaning. The other pup grew slowly until the 36th week on germinated barley. At this time, an attempt to breed him to a female from the stock colony was unsuccessful. Thereafter, he lost weight. He died in the 49th week, at about the same age as had his mother. In addition, five attempts to breed male rats that had received germinated barley for over ten weeks were without success.

Oats. The results of feeding trials with oats were similar to those with barley. Three experimental groups involving 26 rats were followed. For one group of eight rats (Fig. 3), the protein content of the oats and germinated oats was 13.28 and 14.56%, respectively. The four rats fed the oats failed to grow and were dead by the 13th week, but the four animals receiving germinated oats grew almost as rapidly as rats on the stock diet (dotted line) during the first seven weeks. After the 7th week, their rate of growth was less but they attained a maximum weight of about 80% of that of normal mature rats. They were still healthy when the experiment was terminated in the 20th week. In another experiment, the oats and germinated oats contained 15.15 and 16.01% protein, respectively. Each diet was fed to five rats. In this experiment, the animals grew almost as rapidly on the oats diet as did those fed germinated oats, but in neither case did the rats approach the weight of the control animals on the stock diet, or the weight achieved by the rats on the germinated oats in Figure 3. A difference in growth on the two

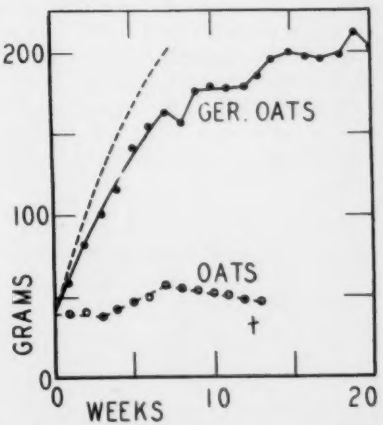


Fig. 3.—Growth of rats on oats and germinated oats. The protein content was 13.28 and 14.65%, respectively. The values are the averages of 4 male rats on each diet. The short dashes represent growth on the stock diet.

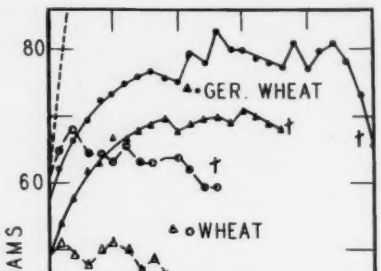


Fig. 4.—Growth of rats on wheat and germinated wheat diets. Each line represents the average weight of four female rats. Wheat from two different seasons is represented. The analysis is in the text. The short dashes represent growth on the stock diet.

diets was not noted until the 18th week when the animals on each diet averaged 110 g. The five rats receiving the oats then lost weight and died by the 22nd week. At the 22nd week, the rats on germinated oats attained their maximum weight (120 g.) which they maintained until the 45th week when they began to die. One rat lived until the 52nd week.

Wheat. Three different experiments with a total of 34 rats were completed with wheat and germinated wheat diets. The results of two of these experiments are graphed in Figure 4. Each represents a winter wheat grown in different years. Each line represents the average weight of four female rats. The rats with an initial weight of 50 g. received wheat and germinated wheat containing 14.9 and 15.8% protein, respectively. The protein content of the diets of the rats with an initial weight of 60 g. was 10.66 and 11.53%, respectively. In both experiments, the rats fed wheat did not grow significantly, and none survived longer than 15 weeks. Those rats receiving germinated wheat grew slowly for about eight weeks, maintained their weight for an additional 10-14 weeks, and then died. In a third experiment with seven rats on each diet, no difference in the growth rate was found. A comparison of the curves in Figure 4 with those in Figures 1-3 shows that rats on the wheat diets had a slower growth rate than those fed barley or oats.

Corn. The growth of rats on corn and germinated corn was less satisfactory than their growth on the other cereals. An experiment which shows that corn can be improved by germination is given in Figure 5.

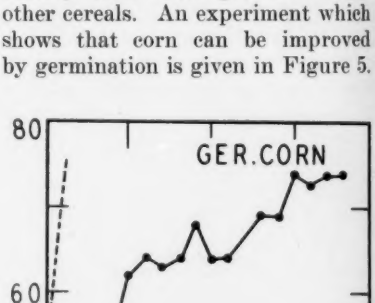


Fig. 5.—Growth of rats on corn and germinated corn diets. The protein concentration of the diets was 9.34 and 9.50%, respectively. The values are the averages of four male rats on each diet. The short dashes represent growth on the stock diet.

TABLE 1.—Weight gain, food consumption, and CER (g. food/g. gain) of rats on germinated and ungerminated cereals.

(Rats on the wheat diets were females, others males.)

Cereal	% N	No. Rats	1st 4 weeks			1st 8 weeks		
			Gain, g.	Food, g.	CER	Gain, g.	Food, g.	CER
Barley	14.97	8	26.7	239.7	8.98	26.6	458.1	17.2
Ger. Barley	16.28	8	44.9	343.0	7.64	69.6	710.0	10.2
Difference			18.2	103.3	5.68*	43.0	251.9	5.9*
Barley	13.81	4	21.	247.	11.76	31.	530.	17.1
Ger. Barley	14.35	4	27.	307.	11.37	44.	655.	14.9
Difference			6.	60.	10.00*	13.	125.	9.6*
Barley	15.13	4	19.	199.	10.47	17.	444.	26.1
Ger. Barley	16.70	4	21.	261.	12.43	43.	722.	16.8
Difference			2.	62.	31.0*	26.	278.	10.7*
Oats	10.17	5	5.	221.	44.2	12.	480.	40.0
Ger. Oats	13.00	5	13.	244.	18.8	20.	536.	26.8
Difference			8.	23.	2.88*	8.	46.	5.7*
Wheat	10.66	4	1.	127.	127.	–2.	229.	.....
Ger. Wheat	11.53	4	15.	175.	11.7	20.	308.	154.
Difference			14.	48.	3.44*	22.	79.	3.6
Corn	9.34	4	–1.	141.	.....	–1.	284.	.....
Ger. Corn	9.50	4	8.	160.	20.0	13.	288.	12.3
Difference			9.	19.	2.11*	14.	4.	0.3*

* The rows labeled "difference" were obtained by subtracting the growth and food consumption on the ungerminated cereal from those on the germinated cereal. The CER was recalculated from these values.

The average weights of four males on corn and germinated corn with protein contents of 9.34 and 9.50%, respectively, are graphed. The four rats fed corn were able to maintain their weight for about 14 weeks when they died. Those receiving germinated corn grew slowly to a maximum weight of 74 g. in 15 weeks, but failed to grow beyond this time and were killed in the 18th week. In two other experiments with other sources of the cereal, the growth of the animals on the corn and germinated corn was insignificant, and the curves were similar to that of the rats receiving the ungerminated cereal in Figure 5. A comparison of Figure 5 with Figures 1-4, as well as the values in Table 1, suggests that corn and germinated corn give the lowest growth rates of the cereals tested when used as the sole source of nutrient.

Food consumption. Food intake data for the first four and the first eight weeks on the various cereal diets are given in Table 1. At-

TABLE 2.

Effect of heat on the nutritional properties of barley and germinated barley.

(Values for the first four weeks on the diets.)

Germinated	Heated		No. Male Rats	Average		
	°C	Hours		Gain, g.	Food, g.	C.E.R.
no	none	.....	6	13.8	195.6	14.17
yes	none	.....	6	23.5	231.7	9.86
Difference	.....	.....	.....	9.7	36.1	3.72*
no	50	48	4	11.5	146.5	12.74
yes	50	48	4	29.8	224.5	7.53
Difference	.....	.....	.....	18.3	78.0	4.26*
no	60	36	3	19.0	182.4	9.60
yes	60	36	3	26.0	249.0	9.58
Difference	.....	.....	.....	7.0	66.6	9.51*
no	75	24	5	9.0	141.6	15.73
yes	75	24	5	24.8	215.4	8.69
Difference	.....	.....	.....	15.8	73.8	4.76*
no	105	24	3	8.	206.0	25.75
yes	105	24	3	2.	278.9	139.9
Difference	.....	.....	.....	-6.	72.9	-12.15*

* Calculated from differences of weight gain and food consumption of germinated and ungerminated barley.

tempts to extend the data beyond this time were of little value because of the slow rate of growth on diets of ungerminated cereal. Comparisons between the cereal and its germinated counterpart for the first four weeks shows a greater weight gain and a larger food consumption for the germinated grain in all cases. On calculating the cereal efficiency ratio (CER, g. cereal/g. gain), the superiority of the germinated cereal is further shown. The CER for the germinated cereal is lower in all cases except the 3rd experiment using barley at the 4-week period, and is considerably lower in all feeding trials for the first eight weeks. By taking the difference in weight gain and food consumption on the diets of germinated and ungerminated grain, the CER due to germination can be calculated. These values are given in the third row in each set of three rows in Table 1. With the exception of the above mentioned experiment, the additional food eaten on the germinated cereal diets gave a lower CER than the ungerminated cereal. For six rats on the stock diet, the CER was 4.37 ± 1.81 and 5.17 ± 2.02 at four and seven weeks, respectively.

Effect of Heating. The stability of the enhanced nutritional properties of the germinated cereals was

tested. Storage for a period of a year, either before or after grinding, did not cause a loss of the enhancement. The extra value of the germinated grain was not affected by moderate heating as shown in Table 2. Heating at temperatures as high as 75° C. for 24 hours did not affect the weight gain of rats or the CER on either the barley or germinated barley diets. The nutritional properties of both types of cereals were inhibited by heating 24 hours at 105°. For these experiments, the ground cereals were heated in kilogram quantities, and the temperature is the average measured at the top and bottom of the mass.

Discussion

The use of germinated cereal in diets has been proposed by many. No attempt has been made to review the subject as the literature is quite controversial and has no direct bearing on the testing procedure used here. By feeding the germinated or ungerminated cereal as the sole ingredient of the diet, the value due to germination is not masked by supplements. Germinated cereals do not have values that cannot be supplied with other nutrients. Further, the value of germinated cereal as used in the present experiments may not be compared directly to the practice of using sprouted cereals as winter forage, although both types of germinated grains may have values in common. In the present studies, the seeds were germinated in the dark and not sufficiently long to produce chlorophyll.

The relative value of the individual cereals is shown in the figures and tables in this paper. Barley and oats are much superior to wheat and corn, and the enhancement of the nutritional value through germination is much greater for the first two. In some cases, an enhanced value of the germinated cereal was not found. This was especially true for corn, and can be expected as all cereal crops do not germinate equally (Pollock, 1958) and errors in the process can lead to poor products. The value of the germinated grains cannot be related to the initial protein content, as the cereals with low protein content were frequently found superior to those with higher concentrations. The greater biological value of the lower-protein cereals is consistent with the findings of Hogan *et al.* (1955) and Sauberlich *et al.* (1953)—that the biological value of low-protein corn is higher than that of high-protein corn. Weber *et al.* (1957) have also shown that lysine and methionine levels of different varieties of oats could not be correlated with the weight gain of rats.

Summary

As has been shown many times before, single, ungerminated cereal diets are found to be poor sources for growth and development of rats. The germination of the cereals enhances their nutritional properties, so that rats fed a germinated cereal diet grow and develop faster, consume more food, utilize the food more efficiently for growth, and live much longer than control animals on

an ungerminated cereal diet. The extra value of the germinated cereal is not lost on storage for periods of over one year, and is not destroyed by heating 24 hours at 75° C.

Literature Cited

Bartlett, J. M. 1917. The composition of sprouted oats. Maine Agric. Expt. Sta., Bull. 266: 287.

Bills, C. E., E. M. Honeywell, A. M. Wibick, and M. Nussmeier. 1931. The critique of the line test for vitamin D. J. Biol. Chem., 90: 619.

Hogan, A. G., G. T. Gillespie, O. Kocturk, B. L. O'dell, and L. M. Flynn. 1955. The percentage of protein in corn and its nutritional properties. J. Nutrit., 57: 225.

Jones, D. B., A. Caldwell, and K. D. Widness. 1948. Comparative growth promoting values of the proteins of cereal grains. J. Nutrit., 35: 639.

Leitch, I. 1939. Sprouted fodder and germinated grain in stock feeding. Imp. Bur. Anim. Nutrit., Techn. Commun. No. 11, 63 pp.

Pollock, J. R. A. 1958. Growth substances in relation to dormancy of barley. Chem. & Ind. (London), 1958: 387.

Raybaud, L. 1929. [Action of germinated grains in nutrition.] Compt. Rend. Acad. Sci. (Paris), 189: 1015.

Sauberlich, H. E., W. Chang, and W. D. Salmon. 1953. Comparative nutritive value of corn of high and low protein content for growth in rat and chick. J. Nutrit., 51: 623.

Weber, E. B., J. P. Thomas, R. Reder, A. M. Schlehuber, and D. A. Benton. 1957. Protein quality of oat varieties. J. Agr. Food. Chem., 5: 926.

Manuscript received June 8, 1960.

SPECTROPHOTOMETRY OF LITMUS AND RELATED INDICATORS

W. N. MOULTON, B. J. WILSON, and C. H. STAFF
Southern Illinois University, Carbondale

Litmus is one of the oldest and most widely used acid-base indicators. The color change takes place over a rather wide pH range in the neighborhood of pH 7. Litmus is prepared by digesting certain lichens, particularly *Roccella tinctoria* and *Lecanora tartarea*, with sodium carbonate and ammonia in the presence of air. If the sodium carbonate is omitted the product is orcein. Litmus can be separated into three indicator components by selective solvent extraction (Elman *et al.*, 1928). The ether-soluble component is erythrolein, the alcohol-soluble component is erythrolitmin, and the alcohol-insoluble material is azolitmin.

Materials similar to those obtained from lichens can be obtained from orcinol or resorcinol (Thorpe, 1948). The material obtained from orcinol on treatment with sodium carbonate and ammonia has been called synthetic litmus, and in the absence of sodium carbonate the product is called orcein. The orceins obtained from orcinol and that from lichens are very similar and usually no distinction is made between the two. Musso (1956) has shown that both are complex mixtures and very similar in nature.

Commercially available litmus is a mixture of colorless plant debris, inorganic salts, and indicator components. Azolitmin and orcein are also commercially available.

In spite of its wide use, it appears that no systematic study of the spectral and indicator properties of litmus, its components, and related compounds has been reported. Spectrophotometric studies to date have been fragmentary and primarily related to use as dyestuffs (Desbleds. 1928) or histological stains (Elman *et al.*, 1928; Ringer, 1950). The present study was undertaken to provide some data on these materials and provide information for structure determination work.

Experimental

Apparatus. Spectral curves were measured with a Cary Model 11 recording spectrophotometer, using 2-cm. quartz cells. Absorbance measurements at fixed wave lengths were made with a Beckman Model B spectrophotometer using 1-cm. Pyrex cells. A Beckman Zeromatic pH meter was used for all pH measurements.

Reagents. All reagents were of the highest quality commercially available. Of the purchased indicators used, litmus and bromthymol blue were from Fisher Scientific Co., orcein was from Eastman Kodak, and commercial azolitmin was from Matheson, Coleman and Bell. All were used without further purification. Other indicators were prepared by methods subsequently described.

Buffer Solutions. Buffer solutions of constant ionic strength were prepared according to the method of Elving, Markowitz, and Rosenthal

(1956) from citric acid, disodium hydrogen phosphate and potassium chloride. The solutions were prepared in 0.5 *M* ionic strength and diluted with an equal volume of water to give the 0.25 *M* ionic strength buffer solutions used in all spectrophotometric measurements. A 0.0833 *M* solution of disodium hydrogen phosphate, ionic strength 0.25, pH 9 was used for measurements at high pH. In one series of experiments, Clark and Lubs phosphate buffers, ionic strength about 0.1 *M*, were used.

Litmus Components. Commercial litmus was extracted with small portions of hot water until the extract came away colorless. The combined extracts were filtered and evaporated to dryness. The residue was triturated with 3 *M* hydrochloric acid. The material that remained insoluble was removed by filtration, washed with water, and dried. This material, which contained most of the indicating matter of litmus and amounted to about 10% of the original litmus, was placed in a Soxhlet extractor and extracted with ethyl ether, and then with 95% ethanol. Evaporation of the ether gave a red gum, erythrolein; evaporation of the ethanol gave a dark red solid, erythrolitmin. The ether- and ethanol-insoluble residue, azolitmin, was an almost black, hard, crystalline material. The composition of a typical sample of crude litmus is given in Table I.

Stock solutions of azolitmin and erythrolitmin were prepared by dissolving 0.25 g. samples in 5 ml. of 0.1 *M* sodium hydroxide and diluting to 100 ml. Stock solution of whole litmus was prepared by refluxing

TABLE I.

Composition of a typical litmus sample.

Component	%
Plant debris	56.8
Inorganic salts	33.2
Erytholein	0.7
Erythrolitmin	4.5
Azolitmin	4.8

10.00 g. of whole litmus with 500 ml. of water for ten hours filtering and diluting the filtrate to 1.000 l. The pH of the stock solution was 9.8.

Synthetic Indicators. A mixture of 0.05 mole of orcinol or resorcinol, 10 ml. of concentrated ammonia, 11 g. of sodium carbonate, and 70 ml. of water was heated on a steam bath in an open flask for twenty-four hours. The solution was cooled and diluted to give 1 l. of stock solution. The solution obtained from the reaction with orcinol was too concentrated for use in the procedure subsequently described. An intermediate dilution of 5 ml. of the reaction solution to 100 ml. with water gave a suitable stock solution. The material derived from orcinol is hereafter designated as orcolitmin, and that from resorcinol is designated resorcolitmin.

Commercial Indicators. Stock solutions of orcein and bromthymol blue were prepared by dissolving 0.050 g. samples in 5 ml. of 0.1 *M* sodium hydroxide and diluting to 100 ml. Commercial azolitmin stock solution was prepared by dissolving a 0.500 g. sample in 10 ml. of 0.1 *M* sodium hydroxide and diluting to 100 ml.

Procedure. Solutions for spectral measurements were prepared by diluting 1- to 5-ml. aliquots of the appropriate stock solution to 100 ml. with buffer solution of the desired

pH. One solution of high pH, one of low pH, and three with pH's near the pK_I, all with the same concentration of indicator, were prepared for each series of measurements. Immediately after preparation the exact pH of each solution was determined and the absorbance at 580 mμ was measured on a Beckman Model B spectrophotometer, and the spectral response curves for the high and low pH solution in the range 400 to 700 mμ were recorded with a Cary Model 11 spectrophotometer. The indicators used were only slightly soluble in acidic solution, and precipitates formed in some acid solutions on standing.

Beer's law studies were made using solutions of high and low pH only, with varying concentrations of indicators.

The same procedure was used in ionic strength experiments except that the calculated amount of additional potassium chloride to give the desired ionic strength was added to the indicator aliquot before dilution with buffer solution.

Solutions of erythrolein were prepared directly from the solid indicator in Clark and Lubs phosphate buffers which were about 0.1 *M* ionic strength.

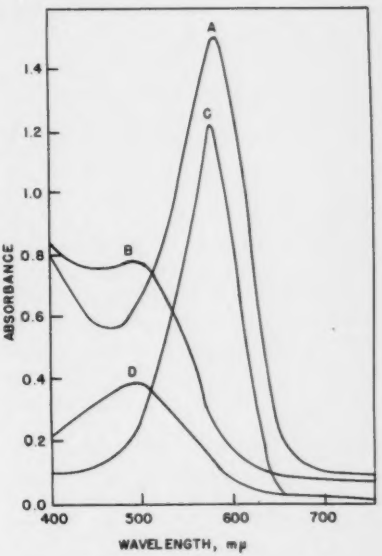


Fig. 1.—Absorption spectra of litmus and orcolitmin.
A=litmus, 5.0 x 10^{-1} g./1., pH 9;
B=litmus, 5.0 x 10^{-1} g./1., pH 3;
C=orcolitmin, 6.2 x 10^{-3} g./1., pH 9;
D=orcolitmin, 6.2 x 10^{-3} g./1., pH 3.

Results and Discussion

It has been generally assumed that each of the three indicator components shown in Table I represented a single chemical compound. Information available to 1948 has been summarized in Thorpe's *Dictionary of Applied Chemistry* (1948). Musso (1956) has shown orcein to be a complex mixture, and this suggests that each of the litmus components is also a mixture. Observations in this laboratory confirm that each component is a mixture, a conclusion based on variable elemental composition, paper chromatography, and spectrophotometric evidence. Only the latter will be discussed in this paper.

Spectral response curves for whole litmus and for orcolitmin, the indicator derived from orcinol, are presented in Figure 1. The curves for all the litmus components and commercial azolitmin are similar to those for whole litmus, and those for orcein and resorcolitmin, the material

TABLE II.—Spectral data.

	pH 3		pH 9	
	λ max mμ	A_s 1000 cm.² g⁻¹	λ max mμ	A_s 1000 cm.² g⁻¹
Whole Litmus	490	0.8	583	1.54
Erythrolein	486	0.8	574	1.3
Erythrolitmin	495	5.6	584	10.2
Azolitmin	498	6.0	587	9.1
Commercial Azolitmin	502	1.9	596	3.8
Orcein	497	37.0	580	138.0
Orcolitmin	497	28.6	580	97.5
Resorcolitmin	490	10.9	590	16.5

prepared from resorcinol, are similar to that of the synthetic litmus. Absorption maxima and absorbancy indices, at high and low pH, for all indicators studied, are given in Table II. There were small variations in spectra of litmus components isolated in one separation when compared with those obtained in other separations. The minimum observed in the 425-475 mμ range for solutions of low pH was not always distinct, leaving a shoulder rather than a peak in the 475-500 mμ range. The most remarkable aspect of the spectra was that while the absorbancy indices varied greatly from one indicator to another, there were only minor differences in the shape of the spectral curves.

Indicator constants were determined in citric acid—disodium hydrogen phosphate buffer with potassium chloride added to maintain a constant ionic strength of 0.25 *M*. The buffers were prepared according to the directions of Elving, Markowitz, and Rosenthal (1956), using one-half the specified concentrations. Additive absorbances were assumed. Deviations from Beer's law for whole litmus and orcolitmin were measured and found to be smaller than experimental error for both the acid and the salt form of both indicators. Assuming ideal behavior the indicator constants were calculated by the equation

$$pK_I = pH_{buf} + \log \frac{A_{Buf} - A_{Alk}}{A_{Acid} - A_{Buf}}$$

where pH_{buf} is the pH of the particular buffered indicator solution, A_{Buf} is the absorbance of that solution, A_{Acid} is the absorbance of a strongly acidic indicator solution, and A_{Alk} is the absorbance of a strongly alkaline indicator solution. The total concentration of indicator was the same for all solutions of a given series, although the ratios of acid form to salt form were different. The results of these experiments are given in Table III. The values for bromthymol blue were measured to give a check on the procedure, and may be compared with the values of 7.10 at 0.1 *M* ionic

strength and 6.9 at 0.5 *M* ionic strength given by Kolthoff and Rosenblum (1937).

Ideally the value obtained for the pK_I of a given indicator should be independent of the pH of the buffer solution in which the measurement is made. However, this is found to be true only for bromthymol blue. Bromythymol blue is a pure compound, but all the other indicators were known or expected to be mixtures, and the spectrophotometric behavior is consistent with this conclusion. The change in the fraction of indicator molecules ionized with change in pH is most rapid when the pH is at the pK_I. Hence, for a mixture of two indicators, the change will be more rapid for the indicator with a pK_I closer to the pH of the solution being examined. Thus, the apparent pK_I of the mixture will be dominated by the indicator whose pK_I is closest to the pH of a given solution. The degree of dominance is dependent not only on pK_I and pH factors but also on the relative absorbances of the species involved. In the present instance, since the pure indicator compounds have not been isolated, no quantitative calculations are possible. The magnitude of this effect can be estimated by calculations for a hypothetical mixture. Assume an equimolar mixture of two indicators each having identical absorbances at a given wave length, in strongly acidic solution, the absorbances in acid and alkaline solution being different. Assume a pK_I of 7.00 for one indicator and a pK_I of 6.00 for the other. If one then makes the usual assumptions of ideal behavior for each component, the apparent pK_I value will be 6.62 in a solution of pH 7, 6.50 in a solution of pH 6.50, and 6.38 in a solution of pH 6.00. A pK_I value of 6.50 would have been found for this mixture if the commonly used graphical procedure was employed in which absorbance is plotted vs. pH for a series of solutions, and pK_I value is taken as the pH at which the absorbance is half-way between that for the strongly acidic and strongly basic solutions.

The effect of ionic strength on pK_I values was determined for litmus and orcolitmin. Relatively high ionic strengths were selected in order to minimize the contribution of the

TABLE III.—Indicator constants in 0.25*M* ionic strength buffer.

Indicator	Solution pH	Calculated pK_I
Whole Litmus	6.22	6.24
	6.60	6.39
	6.98	6.51
Erythrolein[a]	6.3	6.4
	6.8	6.6
	7.2	6.8
Erythrolitmin	6.28	6.48
	6.64	6.58
	7.03	6.69
Azolitmin	6.29	6.72
	6.66	6.76
	7.08	6.93
Commercial Azolitmin	6.30	6.35
	6.63	6.43
	7.08	6.51
Orcolitmin	5.95	6.06
	6.32	6.08
	6.84	6.12
Resorcolitmin	6.30	5.86
	6.62	5.99
	7.03	6.24
Orcein	6.39	6.17
	6.65	6.20
	7.03	6.35
Bromthymol Blue	6.28	6.98
	6.60	6.99
	7.00	6.99

[a] pK_I determinations for erythrolein were made in Clark and Lubs phosphate buffers with ionic strength about 0.1*M*.

indicator stock solution to overall ionic strength and because litmus is not frequently used for the determination of pH of very dilute solutions. Solutions of ionic strength 0.25 *M*, 0.50 *M*, 0.75 *M*, 1.00 *M*, 1.25 *M* were used, and were prepared by adding the required potassium chloride to the standard 0.25 *M* buffers.

Again pK_I values were calculated using buffers of varying pH, and as previously described, the pK_I value increased as the pH of the solution increased. The effect of change in ionic strength on pK_I values was comparable in magnitude to the effect of changing buffer pH as shown in Table III. It was not practical to operate at a constant pH because changes in ionic strength affected the pH of the buffer. In Table IV the average pK_I values of three determinations, each at a different pH, are given for solutions with varying ionic strength. The data shown are representative of those obtained from several samples of indicator. In every case examined the pK_I values were significantly lower at 0.50 *M* ionic strength than at 0.25 *M*, but while further increases in ionic strength tended to decrease the pK_I the results were less consistent and the changes were less pronounced.

All of the indicators investigated are prepared by air oxidation, and each indicator is a mixture of compounds. As a result it is difficult to obtain uniform indicator samples in successive preparations. Instrumental errors in pH and optical absorbance measurements limit the accuracy to $\pm$ 0.1 pK_I unit and

TABLE IV.—Effect of ionic strength on pK_I values for litmus and orcolitmin

Ionic Strength	pK_I Values[a]	
M	Litmus	Orcolitmin
0.25	6.38	6.09
0.50	6.31	5.98
0.75	6.20	6.07
1.00	6.18	5.96
1.25	6.25	6.01

[a] pK_I values given are averages for three determinations, each in a buffer solution of different pH.

reproducibility to $\pm$ 0.05 pK_I unit. Values given in Tables II and III represent results of typical experiments rather than averages. Whole litmus and orcolitmin were the only indicators for which several determinations were made, and values from 0.2 unit lower to 0.2 unit higher were observed, while one sample of orcolitmin consistently gave results about 0.4 of a unit higher, the value varying with buffer pH. The separation process apparently affected litmus components, since all of the individual components exhibited higher pK_I values than whole litmus.

These experiments confirm on a quantitative basis, what is generally known in a qualitative way. Neither litmus nor any of the related indicators are suitable for quantitative work or for colorimetric determination of pH because of the variation of pK_I with pH, the large salt effect, and the uncertainty of composition of a given sample of indicator. The orcolitmin has narrower absorption bands than litmus and the visual color changes are consequently clearer. Orcolitmin also has a much higher absorbancy index and is as easily prepared as litmus solution. On this basis it is recommended as a substitute for litmus. There is no appar-

ent reason why it could not be used for the preparation of indicator paper that would be superior to litmus paper.

Summary

The visible spectra and indicator constants for litmus, three of its components, two related synthetic indicators, and two related commercial products have been measured. All have apparent pK_I values between 6 and 7, but evidence is presented to show that all are mixtures of indicating substances. The effect of ionic strength on the behavior of litmus and the synthetic indicator prepared from orcinol has been determined and found to be large.

Literature Cited

Desbleds, T. B. 1928. The behavior of dyestuff solutions. Cotton, 92: 299-303.

Elman, R., D. R. Drury, and P. D. McMaster. 1928. Litmus constituents as vital stains: their preparation and relative usefulness. J. Exptl. Med., 47: 777-796.

Elving, P., J. Markowitz, and I. Rosenthal. 1956. Preparation of buffers of constant ionic strength. Anal. Chem., 28: 1179-1180.

Kolthoff, I. M. and C. Rosenblum. 1937. Acid-base indicators. New York. The Macmillan Co., p. 293.

Musso, H. 1956. Orcein dyes. II. The separation of orcein into its components. Chem. Bev., 89: 1659-1673.

Ringer, A. 1950. Measurement of absorption in solution of red and yellow dyes. III. Plant dyes. Pharmazie, 5: 385-391.

Thorpe, T. E., ed. 1948. Dictionary of applied chemistry, Vol. VII. New York: Longmans, Green and Co., pp. 372-374.

Manuscript received September 26, 1960.

THE PILOT SHALE, THE WEST RANGE LIMESTONE, AND THE DEVONIAN-MISSISSIPPIAN BOUNDARY IN EASTERN NEVADA

R. L. LANGENHEIM, JR.
University of Illinois, Urbana

Introduction

The boundary between the Mississippian and Devonian systems and the age of the Pilot Shale have concerned stratigraphers in the Great Basin since Hague's first descriptions of the pertinent rocks in the White Pine and Eureka Mining Districts (1870, 1883, 1892). Spencer (1917) and Westgate (Westgate and Knopf, 1932) later named but only briefly described the Pilot Shale and the West Range Limestone. Furthermore, there are few other published descriptions of the generally poorly exposed rocks between the basal Mississippian Joana Limestone and the cliff-forming Upper Devonian rocks of Eastern Nevada. As a result many writers have classified all of the heterogeneous rocks near the Devonian boundary under the name "Pilot Shale". Thus, it appears desirable to present detailed descriptions of well-exposed sections of these rocks in order to prepare a foundation for further, more discriminating study (Fig. 1).

Previous Work

Rocks at the Devonian-Mississippian boundary in Nevada were described early by Hague (1870) as calcareous shales of Devonian age in the White Pine (Hamilton) Mining District (Fig. 2). Later (1883, 1892) he included rocks now considered equivalent to the Devonian shale of the White Pine District in the White Pine Shale as he described it at Eureka. Hague (1882, 1883), however, designated the White Pine Mining District as the source of the name for White Pine Shale. He considered the White Pine Shale Devonian, but, unfortunately, correlated rocks now recognized as Pilot Shale, Joana Limestone, and Chainman Shale at Eureka (Nolan, Merriam and Williams, 1956) with the type section of the White Pine Shale at Hamilton. The type section of the White Pine Shale, however, includes only those rocks equivalent to the Chainman shale of current U.S. Geological Survey usage. Lawson (1906) recognized a lower shale, a middle limestone, and an upper shale in the Robinson (Ely) Mining District which he correlated with Hague's sections at Eureka and Hamilton. Thus, Lawson repeated Hague's error in correlating between Eureka and Hamilton. Spencer (1917) later named the units recognized by Lawson as the Pilot Shale, the Joana Limestone, and the Chainman shale in ascending order. At this time all three formations were referred to the Carboniferous. In 1932 Westgate (Westgate and Knopf, 1932) described the West Range Limestone in the Pioche District and at Dutch John Mountain. As described, the West Range Limestone contains Late Devonian fossils and forms a bench-like outcrop above the Devonian Silverhorn Dolomite and below the Mississippian Bristol Pass (Joana) Limestone. Merriam (1940) later

noted approximately 300 feet of dark argillaceous to shaly limestone ("Zone D") and 85 feet of thin bedded, platy, gray shale ("Zone E") immediately beneath the Mississippian limestone cliff at Dutch John Mountain. Merriam considered these rocks either Devonian or Mississippian, and, on the basis of faunal evidence, placed the base of the shaly sequence 750 feet above the "West Range limestone". In the National Research Council correlation chart of 1942 (Cooper *et al.*, 1942), zone D is referred to the West Range Limestone, and neither zone E nor the Pilot Shale is mentioned. In the comparable Mississippian chart (Weller *et al.*, 1948) the West Range Limestone is referred to the Devonian and the Pilot Shale to the Mississippian. A more recent correlation chart prepared by the Eastern Nevada Geological Association (1953) considers the Pilot Shale as Devonian or Mississippian and definitely refers the West Range Limestone to the Devonian. Nolan, Merriam, and Williams (1956, pp. 52-53) describe a lower calcareous shale with Late Devonian conodonts and an upper platy black, unfossiliferous shale at Eureka as the Pilot Shale. The upper shale is considered Devonian or Mississippian. Reso and Croneis (1959), however, assign 400 feet of Pilot shale resting on 410 feet of West Range Limestone to the Devonian System in the Pahranagat Range. To the southwest in the A.E.C. Proving Ground, Johnson and Hibbard (1957) describe the Narrow Canyon Limestone, consisting of 175

Fig. 1.—Location Map. Line connects locations of measured sections shown in Figure 3.

feet of Late Devonian or Early Mississippian platy, dark gray, buff-weathering silty limestone, that is tentatively correlated with the Pilot Shale, as described by Spencer (1917).

This confusing tangle largely results from a series of detailed local studies of sections in widely spaced areas. Quite properly, the earlier investigators defined local rock units to provide structural datum planes and a stratigraphic framework for their fossil collections. Thus, these rocks are yet to be classified according to their regional extent and significance—an essential part of any investigation of the geologic history of a large area.

Acknowledgments

Field work for this report was conducted during summers of 1954, 1955, 1958, and 1959, Christmas holidays of 1955-1959, and at other short periods during these years. All of this work was primarily directed toward other objectives — regional study of Mississippian rocks, mapping of the Ely No. 3 Quadrangle, and supervision of student research. Acknowledgment is made of assistance in the field by Eugene DeLuchi, Jean Langenheim, Igor Mousastiсoshvily, Larry J. Stensaas, Russell Waines, and Edward Wilson. In addition, Jean Langenheim, Harold W. Scott, and Harold Wanless have read and criticized the manuscript. Field and laboratory work has been supported by the Museum of Paleontology, the Department of Paleontology, and the Faculty Research Committee of the University of California at Berkeley, by the Faculty Research Board of the University of Illinois, and by the Research Committee of the American Association of Petroleum Geologists.

Reference Sections

The Pilot Shale is described by Spencer (1917) as a poorly exposed, nonfossiliferous, soft, black to drab, highly carbonaceous shale 100 to 400 feet thick. Examination in 1955 of the area mapped by Spencer adds little to this information. and the name-giving locality, Pilot Knob, is now covered by waste rock from the Veteran copper pit. The best-exposed nearby section, approximately one mile north of Pilot Knob, shows only a covered slope between the Joana Limestone and an argillaceous buff-weathering, gray limestone containing the *Cyrtospirifer* fauna (Fig. 3). Therefore, an exposure south-southwest of the triangulation station "Willow" on the west flank of the Egan Range and approximately two miles north of the south boundary of the Ely No. 3 Quadrangle has been selected as a reference section for the Pilot Shale (Fig. 3).

At the Willow section, the Upper Pilot Shale consists of 190 feet of nonfossiliferous black, fissile shale. This rock is cleanly exposed and appears to contain little silty or calcareous rock. The upper contact with the Joana Limestone is sharp, as is the basal contact with fossiliferous, calcareous siltstone. The lower 193.1 feet of the Pilot Shale is dominated by black, calcareous siltstone with interbedded silty limestone and minor amounts of fine-grained gray limestone. The basal contact is

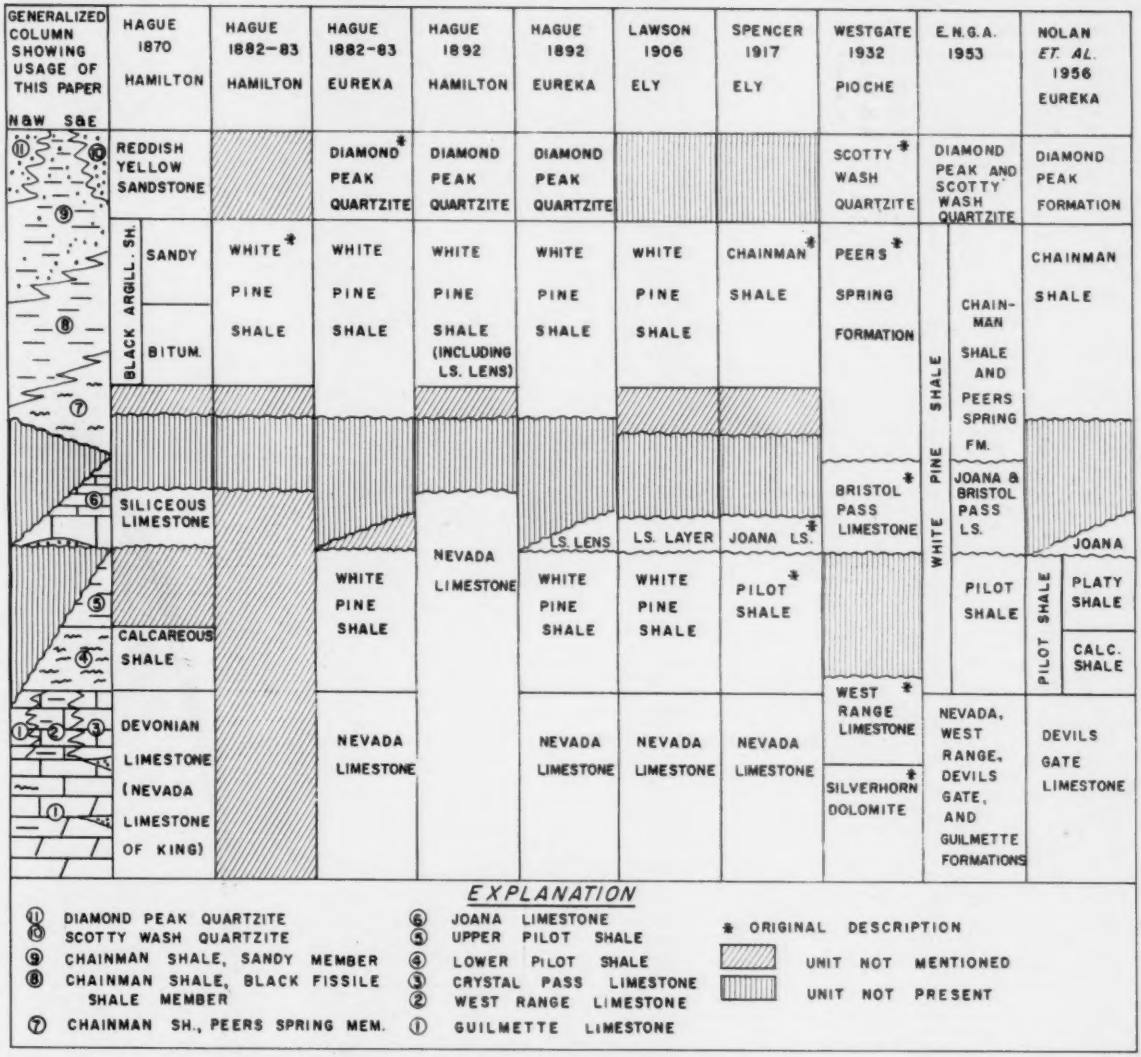


Fig. 2.—Terminology applied to Late Devonian andMississippian stratigraphic units in eastern Nevada.

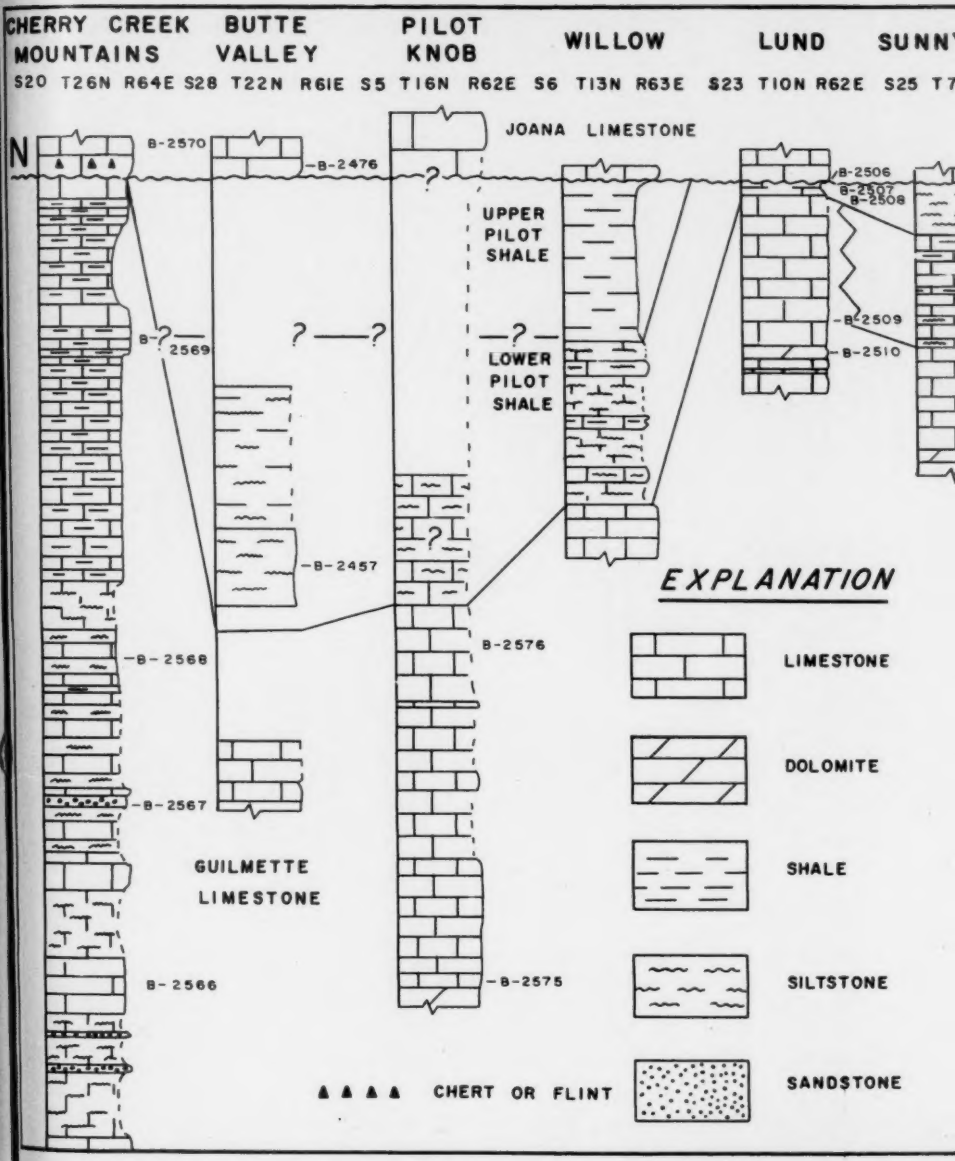
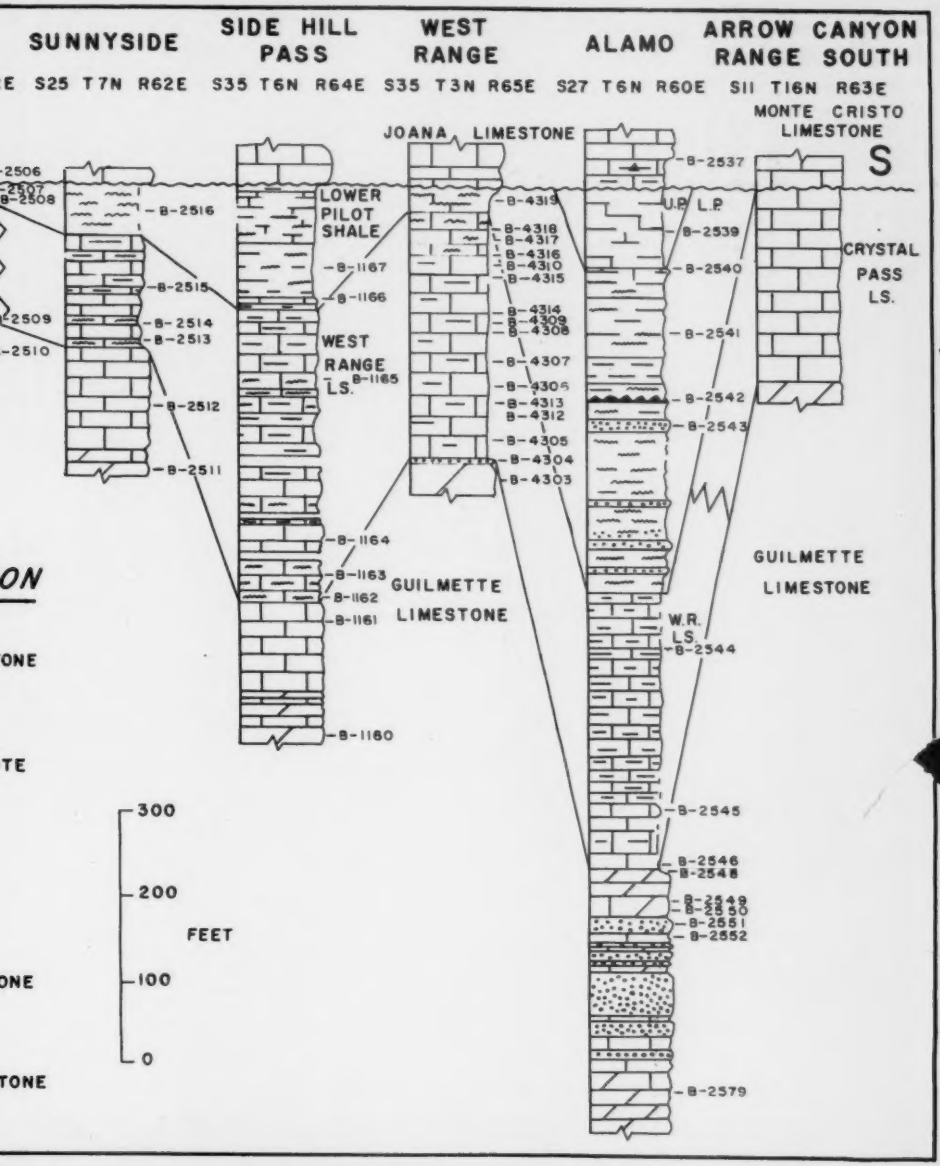


Fig. 3.—Stratigraphic sections of Late Dev



f Late Devonian rocks in eastern Nevada.

sharp, but limestone interbedded in the basal portion of the Lower Pilot Shale resembles the limestone of the Guilmette Limestone below. The silty limestone and fine-grained limestone weather buff and are the probable source of the weathered rock chips covering most Pilot Shale outcrops. The lower Pilot Shale contains abundant fossils including *Nudirostra* sp. of Devonian aspect. A detailed description of the Willow reference section follows:

The 383.1 feet of Pilot Shale at Willow are comparable to the 350 feet of covered rock assigned to the Pilot Shale just north of Pilot Knob (Fig. 2). Thus, it is assumed that the members at Willow are also present at Pilot Knob and underlie the bench between the Joana Limestone and Guilmette Limestone on the west side of Ward Mountain as mapped by Langenheim *et al.* (1959).

Westgate (Westgate and Knopf, 1932, p. 16) describes the West

Unit	Thickness	Description
Joana Limestone		
		Limestone, fine to medium-grained; gray, weathering light gray; beds more than 5 feet thick.
Disconformity		
Upper Pilot Shale		
13	190.0	Shale; black, weathering buff; fissile to platy; homogeneous clay shale with little silty material.
Lower Pilot Shale		
12	2.7	Silty limestone or calcareous siltstone; black, weathering buff; single massive layer; *Nudirostra* sp.
11	21.0	Scattered outcrops calcareous siltstone or silty limestone; black, weathering buff to pink; platy talus.
10	17.0	Limestone, fine-grained; black, weathering buff to gray; beds as much as 1 foot thick separated by calcareous siltstone or silty limestone; fossiliferous.
9	8.5	Calcareous siltstone or silty limestone; black, weathering buff to pink-buff; beds as much as 2 inches thick weathering to plates ¼ inch thick.
8	9.0	Covered.
7	30.0	Scattered outcrops of limestone, very fine-grained; gray, weathering gray to buff-pink in mottled pattern separated by areas of buff soil with chips of silty limestone.
6	3.4	Limestone, fine-grained; black, weathering gray; beds as much as 3 feet thick.
5	7.5	Covered.
4	6.0	Limestone, fine-grained; black, weathering gray; beds as much as three feet thick.
3	44.0	Scattered outcrops and talus of silty limestone or calcareous siltstone; gray, weathering buff to buff-pink; platy.
2	22.0	Limestone, fine-grained; dark gray, weathering gray; beds as much as 1 foot thick separated by units of similar thickness of limestone, fine-grained; dark gray, weathering gray to buff; platy.
1	22.0	Covered.
Guilmette Limestone		
		Limestone, fine-grained; black, weathering mottled gray; beds 1 foot thick.

Total Thickness, Upper Pilot Shale—190.0 feet.
Total Thickness, Lower Pilot Shale—193.1 feet.

Range Limestone as "Blue gray, fine-grained limestone, in some places nodular, commonly weathering to a characteristic yellow color" between a prominent quartzite at the top of the Silverhorn Dolomite and the base of the Bristol Pass (Joana) Limestone. According to Westgate the West Range Limestone ranges in thickness from 330 feet at Dutch John Mountain to 615 feet at the type locality in the West Range and contains abundant Late Devonian fossils of the "*Spirifer whitneyi*" fauna. Inasmuch as the West Range Limestone occupies a stratigraphic position similar to that of the Pilot Shale, has a similar topographic expression, and also is deeply covered by buff-weathered debris, there has been some confusion regarding the distinct character of the two units.

Figure 2 shows a composite of two sections measured at opposite ends of the limited exposure on the conical hill just north of township 2 in the West Range. This is the area designated as the type locality of the West Range Limestone by Westgate (Westgate and Knopf, 1932). Thicknesses as measured are 328 feet at the south end of the outcrop, where the top and bottom of the formation are well exposed, and 350 feet at the northern end of the outcrop, where the uppermost 100 feet of the formation and the contact are covered by talus. Fine-grained, gray limestone in beds one inch to two feet thick dominates. Thinner beds are more argillaceous, tend to be nodular, and contain most of the fossils. Thirty-two feet of platy calcareous siltstone crops out at the top of the southern section. This rock resembles the most abundant rock in the Lower Pilot Shale at Willow and is tentatively assigned to the Lower Pilot Shale. Crinoidal limestone of the Bristol Pass (Joana) Limestone rests on the calcareous siltstone in a sharp contact. The basal contact of the West Range Limestone is a well-marked sharp contact with the upper quartzite member of the Silverhorn Dolomite.

A detailed description of the type section of the West Range Limestone is as follows:

Unit	Thickness	Description
Bristol Pass Limestone (Joana Limestone)		
7		Limestone, fine to medium-grained; gray, weathering light gray; beds more than 20 feet thick.
6	21.0	Limestone, medium-grained; gray, weathering light gray; beds approximately 4 inches thick; *Spirifer centronatus* (?).
Disconformity		
Lower Pilot Shale		
5	32.0	Calcareous siltstone or silty limestone; dark brown to buff or pink buff on weathered surfaces; platy.
West Range Limestone		
4	50.0	Limestone, fine-grained; gray, weathering buff; beds as much as 2 inches thick in lower half, 1 to 2 feet thick in upper half; unit becomes more silty toward top; abundantly fossiliferous.
3	146.0	Limestone, fine to very fine-grained; gray, weathering light gray with pink to buff partings; beds from 1 inch to 2 feet thick with thicker beds at intervals of from 5 to 7 feet; thin-bedded material nodular and more argillaceous; fossiliferous.

Silverhorn Dolomite		
2	3.8	Quartzite, fine-grained; pink-white, weathering white to rusty; bedding not apparent.
1		Dolomite, fine-grained; black, weathering black; bedding not apparent, laminated; *Cladopora* and scattered tetracorals.

Total Thickness, Lower Pilot Shale—32.0 feet.
Total Thickness, West Range Limestone—296.0 feet.

Regional Development of Stratigraphic Units

Throughout the area several thousand feet of cliff-forming carbonate rocks make up the bulk of the Devonian system. Many different kinds of limestone and dolomite, as well as subordinant quartzite and shale, are included in this complex and largely unstudied sequence. This investigation is concerned, however, with only the uppermost portion of these rocks where they are in contact with the shaly and silty rocks of the Devonian-Mississippian transition.

In southern Nevada at the Mormon Mountain, Arrow Canyon Range, Arrolime, and Muddy Mountains sections, the Crystal Pass Limestone is the uppermost Devonian formation. This unit, originally described by Hewett (1931) at Goodsprings, is a very fine-grained, light gray limestone in beds two to four feet thick, which weathers to form a strikingly uniform white band of outcrop between black Mississippian limestone above and layered black and light gray Devonian limestone and dolomite below. Although no fossils have been described from the Crystal Pass Limestone, its gradational contact with the Devonian rocks below and its sharp, apparently disconformable contact with the Mississippian Monte Cristo Limestone above have led to a Late Devonian age assignment.

To the north at Alamo the uppermost part of the Devonian cliff-forming sequence consists of interbedded black dolomite, gray limestone, and rusty weathering quartzite. These rocks differ from the rocks below the Crystal Pass Limestone only in the higher proportion of sandstone in the upper portion, and have been assigned to the Guilmette Limestone by Reso and Croneis (1959). They fit well the original description of the Guilmette Limestone at Gold Hill (Nolan, 1935, pp. 20-21) but contrast sharply with the thick, light gray limestone sequence generally referred to the Guilmette Limestone by petroleum geologists working in eastern Nevada.

At Alamo the Guilmette Limestone is succeeded by 327.4 feet of less resistant limestone assigned to the West Range Limestone. The base of this formation is defined by the top of the highest dolomite bed of the Guilmette Limestone although similar limestone is present in the Guilmette Limestone. Fine-grained, light gray limestone, weathering light gray, occurring in beds as much as two feet thick, is most abundant, but shaly gray limestone, weathering buff, and in nodular layers three inches to one foot thick is also prominent. The formation is fossiliferous and contains elements of the *Cyrtospirifer* fauna as broadly defined. These rocks have been assigned to the West Range Limestone because of composition, weath-

ering character, and position in sequence. They are tentatively considered a more shaly facies equivalent of the Crystal Pass Limestone of the Arrow Canyon mountains.

The West Range Limestone of the type section rests directly on the uppermost quartzite member of the Silverhorn Dolomite (Westgate and Knopf, 1932). Farther north, however, at Side Hill Pass and at Sunnyside, 52 feet and 120 feet respectively of limestone intervene between the uppermost dolomite layer in the Guilmette Limestone and the West Range Limestone. The West Range Limestone is 352.1 feet thick at Side Hill Pass and 137.1 feet thick at Sunnyside. The formation is markedly more silty than at West Range, and detrital material is most prominent at Side Hill Pass where the *Cyrtospirifer* fauna as broadly defined is well represented.

At Lund 179.1 feet of fine-grained, light gray limestone assigned to the Guilmette Limestone is separated from the Joana Limestone by 15 feet of shaly limestone. At the base of this sequence a few intercalated beds of dolomite rest in turn on a much thicker sequence of limestone. Therefore, the West Range Limestone is shown in Figure 3 as terminating south of Lund, where it is replaced by the Guilmette Limestone facies. Alternatively, however, the West Range Limestone may have been eroded at the Lund section and may be present north of Lund in facies relationship with the Guilmette Limestone; it may be represented by one of the shaly sequences within 2518 feet of Guilmette Limestone at Ward Mountain (Willow); or it may be a facies of the Lower Pilot Shale. Further investigation is suggested.

At Willow, Pilot Knob and Butte Valley fine-grained gray limestone in beds as much as four feet thick characterizes the Guilmette Limestone which is here succeeded directly by calcareous siltstone and limestone in the Lower Pilot Shale. At the Cherry Creek Mountains section, however, the uppermost Guilmette Limestone is more silty and argillaceous, forming three units as described below:

Uppermost Unit—408 feet, chiefly fine-grained, gray limestone in beds 2 to 4 inches thick, nodular and with shaly partings.

Middle Unit—336.5 feet, chiefly calcareous siltstone, dark gray, weathering buff, platy; interbedded with minor amounts of limestone as above; includes 19 feet of sandstone 65 feet above the base.

Lower Unit—328 feet, calcareous siltstone and limestone as described above, in alternating sub-units as much as 70 feet thick.

Although the relationship between the Guilmette Limestone, Sultan Formation, Crystal Pass Limestone, and West Range Limestone is poorly understood, a few generalizations are justified. Sandstone is more abundant, at the northern and southern extremities of the study area, with the Alamo and Arrow Canyon Range sections (lower part not shown in Figure 2) characterized by markedly more abundant and thicker sandstone beds. Argillaceous limestone, separately classified in the West Range Limestone, is widespread in the southern half of the area at the top of the Guilmette Limestone but does not occur in the extreme south. Argillaceous limestone and silty limestone are also

prominent to the north at the Cherry Creek and Pequop Mountains sections, but here the argillaceous rocks occur throughout the Guilmette Limestone. In contrast, the Guilmette Limestone of the Butte Valley-Lund area is characterized by predominance of fine-grained, relatively pure, gray limestone.

Rocks assigned to the Pilot Shale occur in the Eureka-Ely area, around Side Hill Pass, and at Alamo. Further north in the Cherry Creek and Pequop Mountains sections, the Joana Limestone rests directly on the Guilmette Limestone, and Nolan (1935, p. 21) reports a similar relationship at Gold Hill, Utah. The Pilot Shale is also absent at Duckwater and Cave Valley. Only 15 feet of buff-weathering gray, noncalcareous shale tentatively is assigned to this formation in the Lund section. Similarly, 32 feet of buff-weathering, calcareous siltstone is referred to the Lower Pilot Shale at the West Range section. The Pilot Shale and its presumed equivalent, the Narrow Canyon Limestone (Johnson and Hibbard, 1957, p. 356), are represented by thick sections at Alamo and Narrow Canyon respectively, but to the southeast the Monte Cristo Limestone rests directly on the Crystal Pass Limestone or older formations.

The section at Willow is the only well-exposed Pilot Shale section studied in the Eureka-Ely area, but the members exposed here appear widespread. Nolan, Merriam, and Williams (1956, p. 52) describe a similar subdivision of the Pilot Shale at Eureka. Furthermore, partial exposures of the basal silty member occur at Buck Pass, Hamilton, and Chainman Mine; the upper black fissile shale member crops out at Buck Pass, Tamburlaine Canyon, and the Chainman Mine. At these localities the basal member consists chiefly of black to dark brown calcareous siltstone that weathers buff. Interbedded limestone also occurs at most localities and is either thin-bedded, shaly nodular dark gray limestone which weathers buff or is fine-grained, gray limestone occurring in beds as much as 2 feet thick which weather gray. Siltstone and limestone occur in both the Guilmette Limestone and Lower Pilot Shale and, in this area, the two formations are distinguished chiefly by the predominance of siltstone in the Lower Pilot Shale. The Lower Pilot Shale also includes fossils of the *Cyrtospirifer* Zone (Merriam 1940, p. 61) as broadly interpreted.

Only the Lower Pilot Shale is recognized in the Sunnyside-Side Hill Pass-West Range Area, where a maximum of 141.2 feet was measured at Side Hill Pass. In this section the lower 64 feet consists of interbedded black fissile shale, calcareous siltstone, and limestone, and the remaining 77.2 feet is chiefly shale and limestone with minor amounts of siltstone. To the east at Dutch John Mountain, however, a thicker section includes both the silty Lower Pilot Shale and the black fissile shale of the Upper Pilot Shale. The Lower Pilot Shale contains *Cyrtospirifer* at these localities.

At Alamo 488.5 feet of silty and argillaceous rock have been tentatively assigned to the Pilot Shale. The Lower Pilot Shale of this area is 351.1 feet thick and is notable for greater thickness and the oc-

currence of sandstone, flint, and abundant non-calcareous quartzitic siltstone. The Upper Pilot Shale at Alamo, 137.4 feet thick, also differs from more northerly exposures of the unit and contains black argillaceous limestone in concretions and thin interbedded layers. No fossils were noted in the Pilot Shale at this locality.

In marked contrast to the rocks just discussed, the Early Mississippian Joana Limestone and Monte Cristo Limestone are remarkably uniform. At all localities the lower portions of these formations consist mostly of fine to medium-grained, gray or black crinoidal limestone in beds ranging from 2 to 20 feet thick. These rocks are generally foetid and may contain flint or chert nodules. One to 20 feet of nodular, crinoidal limestone with shaly partings may occur at the base and 6 inches to 1 foot of basal quartzite was observed at Hamilton, at Buck Pass, and in the Confusion Range of Utah. These rocks lie on a clear-cut plane surface wherever observed and there is no interbedding of the Mississippian crinoidal limestone with any of the older rocks.

Conclusions and Problems

The most important conclusion of this study is that the non-resistant, buff-weathering, poorly exposed rocks between the Late Devonian cliff-forming carbonate beds and the Early Mississippian crinoidal limestone may profitably be assigned to at least three rock units — West Range Limestone, Lower Pilot Shale, and Upper Pilot Shale. In addition, all except the Upper Pilot Shale contain Devonian brachiopods. These units appear conformable with and in part show intertonguing relationships with the underlying Devonian carbonate rocks, but a disconformity is present below the Mississippian crinoidal limestone. Overlap of the detrital rocks by the Joana and/or Monte Cristo Limestone in the Cherry Creek-Pequop-Gold Hill Area and on the shelf in southern Nevada indicates earlier positivism on the shelf and in a large area of northeastern Nevada. This conclusion is reinforced by facies changes toward more and coarser detrital material in the upper Guilmette Limestone to Lower Pilot Shale interval in these areas. Local, pre-Joana positivism is also indicated in the Duckwater, Lund, and Cave Valley region.

At this stage in the development of our knowledge of the latest Devonian and earliest Mississippian history of eastern Nevada several problems seem to have clear priority for further investigation. The Late Devonian faunas require systematic description and thorough stratigraphic study in order that the various facies of the Late Devonian formations may be placed in a biostratigraphic and temporal relationship. The details of the complex facies relationships between the Guilmette Limestone, West Range Limestone, and Pilot Shale are still not adequately understood. Finally, a thorough search for fossils, including the less widely studied groups, must be made in the Upper Pilot Shale if its age is to be definitely determined.

Literature Cited

Cooper, G. A. *et al.* 1942. Correlation of the Devonian Sedimentary Formation of North America. Bull. Geol. Soc. Amer., 53(12): 1729-1794, 1 pl., 1 fig.

Eastern Nevada Geological Association Stratigraphic Committee. 1953. Revision of stratigraphic units in Great Basin. Bull. Amer. Assoc. Petrol. Geol., 37(1): 143-151, 2 figs.

Hague, Arnold. 1870. Geology of the White Pine Mining District. U.S. Geol. Expl. Fortieth Parallel (King), 3:409-421, Atlas Sheet 14.

Hague, Arnold. 1882. Report of Mr. Arnold Hague. Ann. Rept. U.S. Geol. Survey, 2: 1880-81, 21-35, map.

Hague, Arnold. 1883. Abstract of Report on geology of the Eureka District, Nevada. Ann. Rept. U.S. Geol. Survey, 3: 1881-82, 237-290, 2 pls.

Hague, Arnold. 1892. Geology of the Eureka District, Nevada. Mon. U.S. Geol. Survey, 20: 1-419, 8 pls., 9 figs., 13 Atlas Sheets.

Hewett, D. F. 1931. Geology and Ore Deposits of the Goodsprings Quadrangle, Nevada. Prof. Paper U.S. Geol. Survey, 162: 1-172, 40 pls., 55 figs.

Johnson, M. S. and Hibbard, D. E. 1957. Geology of the Atomic Energy Commission Nevada Proving Grounds Area, Nevada. Bull. U.S. Geol. Survey, 1021-K: 333-384, 2 pls., 1 fig.

Langenheim, R. L., Jr. *et al.* 1959. Geology of the Ward Mountain Area, Ely Quadrangle, White Pine County, Nevada (Abstract). Bull. Geol. Soc. Amer., 70(12:2): 1730.

Lawson, A. C. 1906. The Copper Deposits of the Robinson Mining District, Nevada. Univ. Calif. Publ., Bull. Dept. Geol., 4(14): 287-357.

Merriam, C. W. 1940. Devonian Stratigraphy and Paleontology of the Roberts Mountains Region, Nevada. Spec. Paper Geol. Soc. Amer., 25: 1-114, 16 pls., 7 figs., 8 tab.

Nolan, T. B. 1935. The Gold Hill Mining District, Utah. Prof. Paper U.S. Geol. Survey, 177: 1-172, 15 pls., 31 figs.

Nolan, T. B., C. W. Merriam, and J. Steele Williams. 1956. The Stratigraphic section in the Vicinity of Eureka, Nevada. Prof. Paper U.S. Geol. Survey, 276: 1-77, 2 pls., 2 figs.

Reso, Anthony and Carey Croneis. 1959. Devonian System in the Pahranagat Range, Southeastern Nevada. Bull. Geol. Soc. Amer., 70(9): 1249-1252, 1 pl., 2 figs.

Spencer, A. C. 1917. The geology and ore deposits of Ely, Nevada. Prof. Paper U.S. Geol. Survey, 96: 1-189, 15 pls., 4 figs.

Weller, J. M. *et al.* 1948. Correlation of the Mississippian Formations of North America. Bull. Geol. Soc. Amer., 59(2): 91-196, 2 pls., 7 figs.

Westgate, L. G. and Adolph Knopf. 1932. Geology and ore deposits of the Pioche District, Nevada. Prof. Paper U.S. Geol. Survey, 171: 1-79, 8 pls., 13 figs.

Manuscript received April 8, 1960.

SHOOT APICES IN TWO HYBRID JUNIPERS

MARGARET KAEISER
Southern Illinois University, Carbondale

Introduction

The apex of shoots of the Cupressaceae, to which the genus *Juniperus* belongs, is characterized by four recognizable major zones (Fig. 1): Zone I, consisting of the apical initial cells and their anticlinal derivatives; Zone II, the subapical mother cells; Zone III, the peripheral meristem; and Zone IV, the pith mother cells. Apical initials in this family and in the Taxodiaceae are reported to be only four or less per shoot; in these cells periclinal divisions occur (Fig. 4). However, the peripheral surface layer appears as a discrete protoderm. Complete elimination of periclinal divisions has been attained in the permanent shoots of *Taxodium*, and in *Araucaria* (Araucariaceae); these two genera have, therefore, been regarded as possessing a tunica and of having reached the angiosperm level of organization. The expression "potential tunica" is sometimes used for the peripheral surface layer in the Cupressaceae (Al-Sherifi, 1952).

The subapical mother cells of the Cupressaceae have characteristics common to most of the conifers in being few in number, irregularly arranged and poorly defined. This family and the Taxodiaceae (*Sequoia* excepted) have the smallest Zone II of any of the Gymnospermae. Zone III develops as lateral derivatives of cells of Zone II. In the Cupressaceae Zone III is stratified but exceedingly narrow and not clearly separable from Zone II. In contrast, the pith is easily discernible. Zone IV is made up of one to three pith mother cells in this family. However, pith is often observed very close to the apex (Figs. 2 and 3), and no pith rib meristem is formed. The pith zone is also characteristically narrow, a condition considered to be related, possibly, to the highly ramified type of branching of the shoot.

In the present study an analysis has been made of the shoot apices of terminal and first lateral branches in winter and spring periods of growth from two trees selected from a genetically mixed "swarm hybrid population" (Hall, 1952) of *J. virginiana* L. (eastern red cedar) X *J. Ashei* Buchh. (Ozark white cedar). One of the trees shows the characteristically longer terminal branches

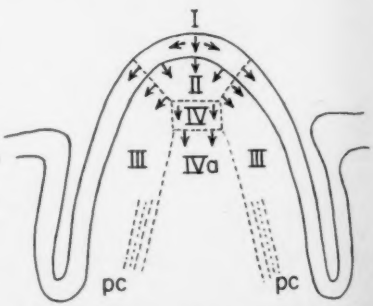


Fig. 1.—Four major zones of shoot apex of Cupressaceae (after Al-Sherifi). I: apical initials and their anticlinal derivatives; II: subapical mother cells; III: peripheral meristem; IV: pith mother cells. IVa and pc are regions of maturing pith and procambium, both situated below actual apical meristem.

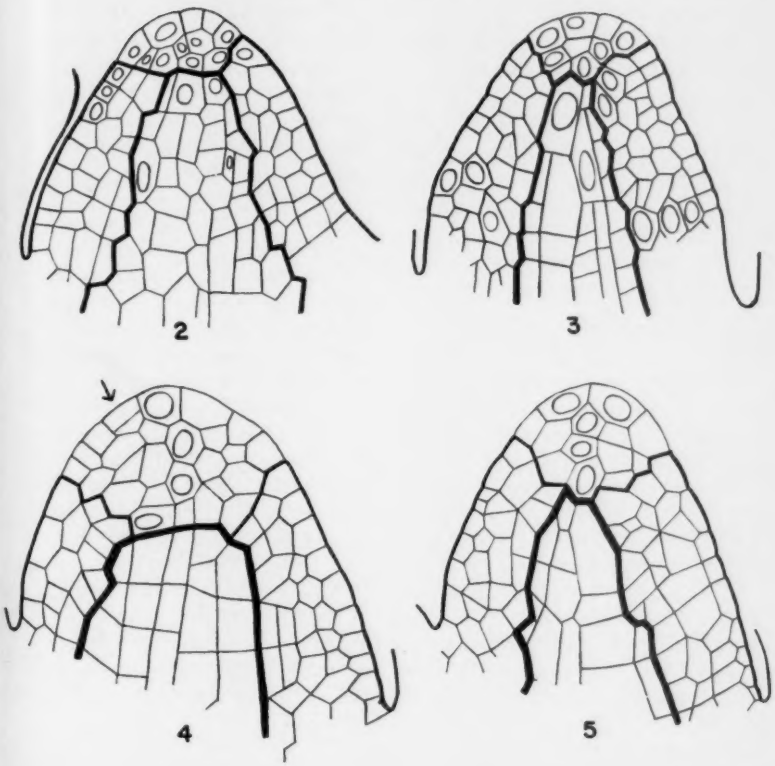


Fig. 2.—Median longisection of shoot apex of long whip. May, 1959. Heavy lines delimit apical meristem above and area of pith. Fig. 3.—Median longisection of shoot apex of lateral of long whip. May, 1959. Fig. 4.—Median longisection of shoot apex of short whip. May, 1959. Fig. 5.—Median longisection of shoot apex of lateral of short whip. May, 1959.

(long whips), as well as certain leaf characteristics of *J. virginiana*, whereas the other one possesses only short terminal branches (short whips) and whip and spur leaves of the *J. Ashei* type. The choice of these two segregates rests on the assumption that it is advantageous to have plants from a similar genetic background. Herbarium specimens are on deposit at the Herbarium of Southern Illinois University, along with typical *J. Ashei* from near Eureka Springs, Arkansas, and typical *J. virginiana* from the Nashville Basin procured by the writer. Not all of the external structural features of the two segregates selected are identical with *Ashei* or *virginiana*, but the terminal branch pat-

terns are remarkably close in the two trees selected from the naturally growing population.

Acknowledgments

The writer wishes to thank Drs. Edgar Anderson and M. T. Hall for identification in the field of the specimens used. The interest of Dr. E. W. Sinnott in the study is also gratefully acknowledged.

Materials and Methods

The two trees selected are in a natural population of cedars located approximately seven and one-half miles south of Carbondale, Illinois on limestone outcroppings on a hillside near U. S. Highway 51. One of the trees shows much longer terminal branches than the other.

Shoot apices were killed and fixed in F.A.A. Infiltration followed the usual procedures with ethyl alcohol-tertiary butyl alcohol series, and the specimens were embedded in paraffin (Johansen, 1940). Serial longitudinal sections were cut at 10 μ. Very lightly stained sections using Safranin O and Fast Green FCF proved most satisfactory in delimiting apical meristem from adjacent areas. Median longisections were selected for comparisons. Twelve apices of each type were collected in February and again in May. These included long terminals and their first laterals and short terminals and their first laterals. From these four to six median longisections of each type from each collection were obtained. The number of samples analyzed was arbitrarily chosen and the samples themselves were random ones. Samples from both trees were collected on the same collecting trip of each month.

Square millimeter area determinations were made from camera lucida drawings with the use of a planimeter. Included angle readings within the shoot apices at various levels were also made from camera lucida drawings, using a protractor. By included angle is meant that angle read in degrees from apex of shoot to outer limits of level of flanking tissue, pith, or first leaf. Square millimeter areas of apical meristem included the outlines of tips of stems that were clearly differentiated in the staining process from underlying areas (Figs. 2-5). The upper level of pith, as indicated, was easily determinable, as was the level of the first leaf. The level of flanking tissue is interpreted to indicate the upper level of first detectable periclinal walls in the sub-protodermal areas (i.e., peripheral meristem of Zone III). All measurements are shown in Table 1.

Results

The results of the studies are summarized in Figure 6 and Table 1. Outlines in Figure 6 are drawn to scale. Therefore, actual size differences can be easily noted. The uppermost horizontal lines indicate the level of flanking tissue, the next lower ones the level of pith. The lowermost limits of the diagrams indicate the positions of leaves. Proportionate differences are more easily read from Table 1.

Long Whips

The stem apex of the long whips is proportionately the largest of any

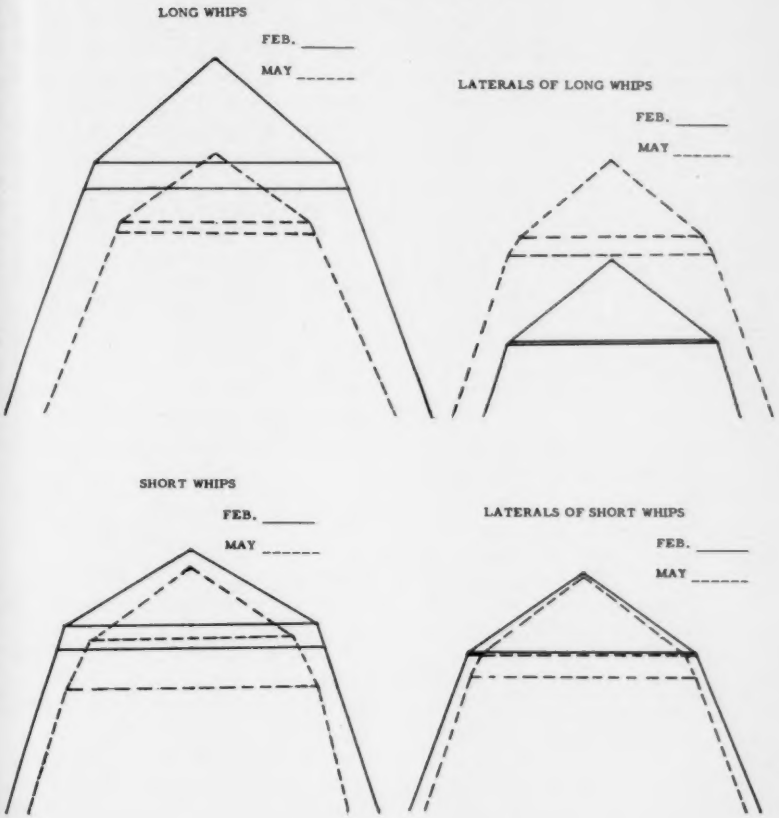


Fig. 6.—Diagram to show relative distances of upper level of flanking tissue (uppermost horizontal lines); upper level of pith (next lower horizontal lines); and upper level of first leaf (lowermost limits of outlines) from shoot apex in long and short whips and in their first lateral branches.

in the late winter when it is interpreted to include the volume from apex to the level of the first leaf. By late spring the long whip apex has become smaller but proportionately broader and lower and with its first leaf proportionately closer to the summit. Its pith is now nearest to the summit of any of the types reported. The amount of apical meristem has decreased markedly and is the smallest of any of the shoot types. The readings of included angles at the levels of first detectable flanking tissue, pith and first leaf all show an increase over

TABLE 1.

		Included Angles of Shoot Apices	Areas of Shoot Apex within Included Angles (mm.²)	Ratios of Diameter of Shoot Apex to Height	Areas of Apical Meristem (mm.²)	Included Angles of Shoot Apices	Areas of Shoot Apex within Included Angles (mm.²)	Ratios of Diameter of Shoot Apex to Height	Areas of Apical Meristem (mm.²)
LONG WHIPS									
	LEVEL OF:	TERMINALS				FIRST LATERALS			
February	Flanking Tissue	100°	0.139	2.55	.....	102°	0.106	2.50	.....
	Pith	97°	0.195	2.21	(0.159)	101°	0.112	2.52	(0.119)
	First Leaf	65°	1.154	1.24	.....	79°	0.300	1.63	.....
May	Flanking Tissue	104°	0.079	2.77	.....	101°	0.080	2.46	.....
	Pith	103°	0.096	2.52	(0.097)	98°	0.132	2.20	(0.102)
	First Leaf	68°	0.664	1.35	.....	64°	0.601	1.26	.....
SHORT WHIPS									
	LEVEL OF:	TERMINALS				FIRST LATERALS			
February	Flanking Tissue	120°	0.102	3.42	.....	112°	0.097	2.96	.....
	Pith	106°	0.195	2.77	(0.148)	111°	0.110	2.88	(0.148)
	First Leaf	73°	0.759	1.46	.....	75°	0.630	1.51	.....
May	Flanking Tissue	115°	0.076	3.00	.....	104°	0.093	2.68	.....
	Pith	98°	0.212	2.13	(0.159)	98°	0.138	2.28	(0.118)
	First Leaf	71°	0.630	1.40	.....	71°	0.555	1.39	.....

the late winter ones. The ratios of diameters to height of shoot at the same levels, comparatively, all show increases. It may be noted that within each series, as the ratios increase the included angles become greater. Conversely, as the ratios decrease the angles become less.

Short Whips

Short whip shoot apices at the three levels measured are smaller in size than long whips in the late winter season.. They are proportionately broader with their first leaves and upper level of flanking tissue

closer to the apex. In the later collections the short whip apices also become smaller than in late winter. The level of pith is now farthest from the apex of any of the types reported. The actual amount of apical meristem increases somewhat instead of decreasing as the season progresses. This is the converse of the situation in the long whip apices. The readings of included angles decrease in the May collections instead of increasing as do those of the long whips. Likewise, the ratios all show a corresponding decrease in later collections, again in contrast to the changes in the long whips.

Laterals of Long Whips

The lateral shoot apices of the long whips are the smallest in late winter of any of the types reported. In contrast to the long whips their over-all dimensions increase in the later collections. However, the upper level of the pith becomes proportionately lower, whereas the upper level of the flanking tissue occurs at a higher level by May. The amount of apical meristem decreases. The included angles all decrease. The ratios of diameters to height, comparatively, also show decreases in the later collections.

Laterals of Short Whips

The lateral shoot apices of the short whips are smaller than those of the short whips at the first leaf level in the earlier collections; their dimensions decrease in the later collections, as do those of the short whips. The pith level, likewise, is lower but the upper level of flanking tissue is higher. The amount of apical meristem, the included angles and the ratios all decrease as the season progresses.

Significant structural features among the four types of shoot apices are as follows. Larger sized long whip apices occur during the late winter with a proportionately rather low level of pith and with the lowest first detectable level of flanking tissue and the second lowest included angle of shoot apex at the level of the first leaf. Smaller sized long whip apices are found in the later collections having the highest level of pith, the second highest level of flanking tissue and the third lowest included angle of shoot apex at the level of the first leaf. The first leaf appears proportionately somewhat closer to the apex, but this long whip apex is actually the highest of any of the types with its first leaf farthest from the apex. Short whip apices are lower and proportionately broader than those of the long whips, becoming narrower in the later collections and with the highest level of flanking tissue and the lowest level of pith. The first leaves are actually closer to the shoot apex than are those of the long whips.

Apices of first laterals of the long whips are proportionately broader and much lower than their terminals at the first leaf levels, but they become proportionately narrower than the terminals later in the season, although there is a marked increase in size. Earlier collections show them to be the smallest in size of any of the shoot apices. They are unlike any of the other shoot types in that they show an increase in size by the later date. Apices of the first laterals of the short whips, like those of the short whips themselves,

become smaller and proportionately narrower at the later date. Pith level also becomes relatively low. In contrast to laterals of long whips they show a decrease instead of an increase in size as the season progresses, and their included angles read at levels of flanking tissue, pith and first leaf are all greater.

Discussion

From the measurements of the apices of long and short branches it is apparent that the rate of development is fundamentally different in the two types. Even though pith occurs relatively near the summit in members of the Cupressaceae, when compared to those of other families of conifers, in the vigorously growing short whips it is relatively low, whereas it is extremely high in the long whips. This may be correlated with the relatively much greater amount of apical meristem tissue in the short whips at this time. The short whips at the level of their first leaves still remain proportionately somewhat broader and lower than the long whips with their first detectable periclinal divisions in the sub-protodermal region (peripheral meristem of Zone III) at an extremely high level. In general during this period the first laterals of the short whips resemble their terminals more closely than do the laterals of the long whips. However, they do share similarities as apices of laterals: decrease in included angles; decrease in their ratios; decrease in the total amount of apical meristem; and in both types the level of pith drops.

How even a very irregular mass of cells gets itself straightened out into a formed structure poses one of the most difficult problems of morphogenesis. The differences in rate of development of the shoot apices is highly suggestive of auxin differences. More important than the layering in the meristem, perhaps, are the physiologically genetic differences between the two tree types. Layering, for example, may or may not occur during certain growth phases of apices (Parke, 1959); however, the end results show quite different shapes of apices and proportions of their recognizable parts (Fig. 6). There is need for periodic collections over several seasons' growth before deciding upon the significance of layering, if any. In itself it appears to have little significance. It is possible that it is intimately connected with initiation of leaf primordia. But this, in turn, would be correlated with rate of cell divisions of the inner portions of a meristem, for we know that if the inner portions of a meristem are growing faster than the outer ones, the outer tend to be layered.

According to Hall's hypothesis the individual trees in the population with long whips reflect more "*virginiana*" genetically in this respect, whereas those with only short whips are more like "*Ashei*". The structural differences observed in the apices from the tree with long whips and from the tree with short whips only would, according to the hypothesis, reflect differences in the genetic constitution of the two individuals.

The future character of the shoot seems to be determined by the character of the shoot apex from which

it arises. Certain effects of environmental factors would be expected, and a certain amount of plasticity of apex, and therefore shoot character, probably exists. The differences between long and short shoots appear to be fundamentally comparable in character, however, to the long and dwarf shoots of *Ginkgo* (Gunckel *et al.*, 1949).

The relations between terminal and lateral apices determine the specific forms in the plant itself. The differences noted could well be the result of auxin distribution, although what determines differential distribution of auxin is not known.

Any relationship or correlation that may exist between the apices of long and short whips and ontogenetic differences in the types of leaves developing from them remains to be investigated. With the pronounced difference in appearance and behavior of these two kinds of apices it appears that the rate of leaf formation is fundamentally different. It is possible that there is a correlation with, if not a controlling influence of the rate of growth of apex to the rate of development of different portions of the leaf types formed. If this is the case, the classification of leaf types found would be referable to the growth pattern of the apex itself.

Summary

Differences in the patterns of growth in stem apices of long and short whips and their first laterals, as reflected by i) increase or decrease in volume from winter to spring; ii) changes in included angles read from apex to upper levels of flanking tissue, pith and first leaf; and iii) shifts in discernible amounts of apical meristem, are given.

1. In the spring the apex of the long whip is outstandingly different in having the smallest amount of apical meristem and the highest level of pith. It becomes proportionately somewhat broader at the first leaf level, instead of proportionately narrower, as in the case of the short whips. Its first leaf, however, remains the greatest actual distance from its shoot apex of any of the four types.
2. Unlike the other types of apices, the laterals of the long whips increase in size from the level of first leaf as the season progresses.
3. In the spring the apex of the short whips has the largest amount of apical meristem, the lowest level of pith and the highest level of flanking tissue. It is also the broadest of any apex, proportionately, at the first leaf level.
4. In the later collections the laterals of both long and short whips are alike in being smaller than their respective terminals, but the apices of the laterals of the short whips are proportionately broader than those of the long ones. In this respect they resemble more closely their own terminals.
5. According to Hall's hypothesis the differences in the types of apices would be regarded as inherent ones, reflecting differences in genetic constitution of two

individuals of a natural hybrid population of *J. virginiana* X *J. Ashei.*

Literature Cited

Al-Sherifi, Khidher Abbas. 1952. Histological Studies on the Shoot Apices and Leaves of Certain Cupressaceae. Ph.D. Diss., Univ. of Calif.

Gunckel, J. E., K. V. Thimann and R. H. Wetmore. 1949. Studies of development in long shoots and short shoots in *Ginkgo biloba* L. IV. Growth habit, shoot expression and the mechanism of its control. Amer. Jour. Bot., 36: 309-316.

Hall, M. T. 1952. Variation and hybridization in *Juniperus.* Ann. Mo. Bot. Gard., 39: 1-64.

Johansen, D. A. 1940. Plant microtechnique. New York, McGraw-Hill Book Co., xi + 523 pp.

Parke, R. V. 1959. Growth periodicity and the shoot tip of *Abies concolor.* Amer. Jour. Bot., 46: 110-118.

Manuscript received April 22, 1960.

UNUSUAL COAT COLORS IN SOME WILD AMERICAN CARNIVORES

DONALD F. HOFFMEISTER
Museum of Natural History, University of Illinois, Urbana

Undescribed coat colors in wild carnivores are few. However, examples of melanistic ringtails, *Bassariscus astutus,* and albinistic mink, *Mustela vison,* have recently been seen.

Bassariscus astutus. — Ringtails are not recorded as having dark color-phases. However, two individuals recently obtained, a male and female, are exceptionally dark and as dark as or darker than the silver phase of the red fox, *Vulpes vulpes.* These two ringtails were taken by a fur-trapper within a 25 mile radius of Llano, Texas. They were sent to the Maas and Steffen Fur Company, St. Louis, Missouri, where Mr. E. C. Steffen, Jr., saw five others, equally dark, during the same fur season of 1959-1960.

The entire dorsum and sides of these animals are black. The normally white patches below the ear and around the eye are brownish. The light-colored "rings" on the tail are more nearly cream than white. The underparts, instead of being a creamy color, are a mixture of black, gray, and brown, with the brown primarily along the midline and in the inguinal region. When the dark hair on the back is parted, the underfur appears lead-colored, only slightly darker than in the "wild type".

This melanistic or silver phase appears to be uncommon. In the 1959-1960 fur season, Mr. Steffen had handled 17,437 ringtails by May 6, 1960, and had seen only seven such individuals. This would be one "silver" in about every 2500 wild type. In previous years dark ringtails were seen in about this same ratio.

All seven of the "silvers" are from a relatively small area in central Texas: near Junction, Fredericksburg, Stonewall, Marble Falls, and Llano.

Mustela vison.—Mink, reared in captivity as fur-farmed animals, are known to display numerous mutations affecting coat color. However, in the wild, such variants are rarely or never encountered, except in those few cases where mutant ranch-mink have escaped and bred with wild mink. In the 1959-1960 fur season, Steffen and Maas Fur Company obtained a light-colored, almost white, mink taken by Mr. Carl W. Evon along a creek at Manukutak, Dillingham, Alaska. This mink has white underfur but the guard hairs are tipped with a light yellowish brown, giving the animal a uniform frosting of a color similar to but much more dilute than in "New Zealand" of rabbits. The animal appears to be whitish, but it obviously is not an albino. Of the various mutations described by Shackelford (Genetics of the ranch mink, 1950, Pilsbury Publ., Inc., N. Y., 91 pp.), *albino* (c^Hc^H) and dominant white (SS or FfSs) would seem closest to this wild-taken specimen. The color of the Dillingham specimen fits the description of neither of these exactly, however, and probably the animal has a different genotype.

Fig. 1.—Dorsal and ventral views of melanistic and normally colored ringtails, *Bassariscus astutus* (x 2/11). Left to right: UI, no. 22700, near Llano, Texas; UI, no. 15158, Tucson Mts., Arizona; UI, no. 22699, near Llano, Texas; UI, no. 5825, Graham Mts., Arizona.

About 10 years earlier, the same fur company obtained another light-colored mink, somewhat like the Dillingham specimen but more yellowish. This was taken about 200 miles north, on the Yukon River near Holy Cross, Alaska. In nearly 30,000 wild mink from Alaska handled by Mr. Steffen over the last 15 years, these two are the only mutants he recalls. His father, handling Alaskan mink for the past 50 years, saw only one other light-colored mutant.

A "white" mink, caught at New Baltimore, southwestern Ohio, in May, 1960, was brought to Mr. W. W. Goodpaster, a taxidermist and naturalist in Cincinnati, to prepare as a mounted specimen. This specimen is cream-colored but an albino, with pink eyes. The mink was chased by a domestic cat into a stone pile where the mink was netted. This would be a peculiar behavior for a mink with normal vision.

Manuscript received May 26, 1960.

A CONCEPT CONCERNING A SET WITH A BINARY COMPOSITION LAW

A. A. MULLIN
University of Illinois, Urbana

Introduction

This paper deals with a development of a side-problem concerned with the author's physico-logical researches in biological computation (Mullin, 1958, 1959, 1960). In particular, the paper is concerned with a unifying concept associated with sets that possess a closed binary composition law.

Basically we will concern ourselves with anticlosed subsets of closed systems. Some pertinent theorems are developed for general systems and systems with the structure of a group.

General Case

Definition 1.1: Let (B,*) denote a nonempty set B together with a closed binary composition law "*" defined on B. Call (B,*) an algebraic system. By a *mutant* of (B,*) is meant a subset M of B which satisfies the condition

$$M * M \subseteq \overline{M},$$

where $M * M = \{ a * b : a \in M, b \in M \}$ and $\overline{M}$ is the set of all of the elements of B not in M. Clearly M must be a proper subset of B. If all of the elements of B are idempotent with respect to "*" then the empty set is to be considered the only mutant of (B,*). With this convention every algebraic system has a mutant.

Theorem 1.1: Every subset of a mutant M of (B,*) is a mutant of (B,*).

Proof: $A * A \subseteq M * M \subseteq \overline{M} \subseteq \overline{A}$, for every $A \subseteq M$.

Theorem 1.2: Let $\{ S_i : i \in I \}$ be a nonempty class of mutants of (B,*). Then

(i) $\bigcap_{i \in I} S_i$ is a mutant of (B,*)

and

(ii) $(\bigcap_{i \in I} S_i) * (\bigcap_{i \in I} S_i) \subseteq \bigcap_{i \in I} \overline{S}_i$.

Theorem 1.3: Let φ be a homomorphism from (A,*) into (B, o). Let M be a mutant of (A,*). If $\varphi(\overline{M}) \subseteq \overline{\varphi(M)}$ then $\varphi(M)$ is a mutant of (B, o).

Proof: $\varphi(M) \circ \varphi(M) = \varphi(M * M) \subseteq \varphi(\overline{M}) \subseteq \overline{\varphi(M)}$.

Theorem 1.4: Let φ be a homomorphism from (A,*) onto (B, o). Let M be a mutant of (B, o). Let C be the inverse image of M under the homomorphism. Then C is a mutant of (A,*).

Proof: for each $d_i \in M$ there exists a $c_i \in C$ such that $\varphi(c_i) = d_i$. But $\varphi(c_k * c_i) = \varphi(c_k) \circ \varphi(c_i) \in \overline{M}$. Then $c_k * c_i \notin C$, for otherwise, $\varphi(c_k * c_i) \in M$, which is a contradiction.

Theorem 1.5: Let M be a mutant of (B, o). Then there is no homomorphism from a closed subset of S of $\overline{M}$ into M.

Proof: Assume that there exists such a homomorphism φ. Then for $s_1 \in S$ and $s_2 \in S$, $\varphi(s_1 \circ s_2) = \varphi(s_1) \circ \varphi(s_2) \in \overline{M}$. But since $s_1 \circ s_2 \in S$, $\varphi(s_1 \circ s_2) \in M$.

Theorem 1.6: Let φ be an isomorphism from (A,*) onto (B, o). Then each mutant in either system induces a mutant in the other system.

Definition 1.2: A mutant M of (B, o) is said to be a *maximal mutant* of (B, o) provided there is no mutant of (B, o) which properly contains M. If all of the elements of B are idempotent with respect to "o" then the empty set is to be considered the only maximal mutant of (B, o). With this convention and using Zorn's lemma it is clear that every algebraic system has a maximal mutant.

Theorem 1.7: Every mutant of (B, o) is contained in some maximal mutant of (B, o).

Proof: Apply the Kuratowski Lemma, which states that each chain of a partially ordered set (set inclusion in our case) is contained in a maximal chain.

Theorem 1.8: If N is a proper subset of a mutant M of (B, o) then N is not a maximal mutant of (B, o).

Theorem 1.9: Let φ be an isomorphism from (A,*) onto (B, o). Then each maximal mutant in either system induces a maximal mutant in the other system.

Groups

In this case we assume (A,*) has the algebraic structure of a group. As an example put (G, +) equal to the additive group of integers. Then the set of all odd integers is a maximal mutant of (G, +) and the set of all even integers is a subgroup of (G, +).

Theorem 2.1: Let (G,o) be a group. Then the only non-mutant (left or right) coset of a subgroup (H,o) is H.

Theorem 2.2: Any group isomorphic to the additive group of integers (A) has no finite maximal mutants, (B) has infinite maximal mutants which

(i) have no elements in common
(ii) have a finite number of elements in common
(iii) have an infinite number of elements in common

Theorem 2.3: Any group isomorphic to the additive group (G,+) of integers has a collection C of mutants such that the cardinality of C is that of the continuum.

Summary

This paper defines a new concept concerning a set with a binary composition law. The concept is a relative anticlosure property. A number of theorems are developed, which show how the concept leads to new mathematics and how the concept is related to other mathematics.

Literature Cited

Mullin, A. A. 1958. A residue test for boolean functions. Trans. Ill. St. Acad. Sci., 51 (3/4): 14-19.

Mullin, A. A. 1959. Combinational relay switching fields. Trans. Institute of Radio Engrs., PGEC, 8 (4): 499.

Mullin, A. A. 1960. Some remarks on a relative anticlosure property. Amer. Math. Soc. Notices, 7(4): 480.

Manuscript received May 26, 1960.

SEVERE SUMMER HAILSTORMS IN ILLINOIS DURING 1915-50

STANLEY A. CHANGNON, JR.
Illinois State Water Survey, Urbana

PURPOSE

As part of a hydro-climatological program for studying hail in Illinois, an investigation of days with severe summer hailstorms was made. In a 36-year period, 1915-50, the 18 days having the most severe hailstorms were selected for analysis.

One purpose of this study was to determine the amount of possible monetary loss from one storm, which is valuable information for agricultural interests and for insurance companies. Another purpose was to increase our knowledge of the meteorological characteristics at the surface displayed by severe hailstorms. It was desired to ascertain which, if any, surface characteristics of these storms correlated well with the amount of damage produced.

This study was made feasible by the availability of detailed U. S. Weather Bureau data. Large damage-producing hailstorms are well catalogued (Flora, 1956), and much more extensive data are available for these storms than for other more minor hailstorms.

Factors investigated in each storm include date and time of day, duration, maximum stone size, path size, and areal distribution. The association of the hailstorms with other types of weather, including rainfall and severe weather such as high winds and tornadoes, was studied. The types of synoptic weather producing these storms were determined also.

AVAILABLE DATA AND ANALYTICAL PROCEDURES

The original station records kept by the cooperative observers at the U. S. Weather Bureau stations in Illinois together with published and unpublished notes of the U. S. Weather Bureau furnished hail loss values for individual hail days occurring in the 1915-50 period. Summer was selected for the study period because more than 80% of the crop damage in Illinois from hail occurs in the months of June through August (Stout, Blackmer, Changnon, and Huff, 1959). It was decided to define hail severity by using the two parameters of normalized monetary loss from crop and property damages and per cent of farm value lost. Possibly, criteria such as stone sizes, path sizes, and areal distribution should be used to establish hailstorm severity in a climatological analysis, but data on these criteria are not as detailed nor as reliable as are the monetary loss data.

In order to determine the 18 most severe storm days on a monetary basis, it was necessary to normalize the data for the changing dollar value of crops and property in the 36-year period. It was also necessary to express the normalized crop loss as a per cent of the annual farm value for each year, in order to adjust the crop loss for changing acreage in crops and yield per acre. These crop losses were normalized to the 1910-14 index of prices received by farmers for grain and hay

crops (Illinois Agricultural Statistics, 1949). Similarly, property losses were normalized using index of prices paid for building materials based on the 1910-14 period. The annual farm value is a figure also normalized to this period. The 1910-14 period was used as the price reference period because of the stability of prices in that 5-year period and because Illinois agricultural statistics are based upon this period.

For each of the 40 days with the most severe hailstorms in the 1915-50 period the monetary loss from crops and property, after normalizing, and the per cent of annual farm value lost were computed. The total monetary values for each storm were compared and ranked, with rank one the highest value. The percentages of annual farm value losses for each storm also were compared and ranked, with the highest percentage assigned rank one. Therefore, for each storm, two separate rankings were obtained. These two rankings were averaged to obtain a single, final rank for each storm day. These average rankings were compared and the 18 highest ranked were selected as the 18 most severe hailstorm days in the 1915-50 period.

To measure the areal extent of hail in order to compare storm days, two methods of evaluation were used. A county occurrence evaluation was used, by which hail occurrence in any portion of a county was recorded as a county occurrence. In most instances an entire county was not affected by hail, but this method for describing areal extent of hail was useful because counties represent analytically convenient divisions of Illinois. The second method for evaluating areal extent utilized records from 40 U. S. Weather Bureau stations in and near Illinois. Each station had reliable hail records for the 1915-50 period, and the number of stations reporting hail on each storm day could be determined for measuring areal extent.

Analytical Results

Temporal Occurrence

Eighteen severe hailstorm days in the 36-year period were selected to furnish a sample number which would make each storm day equivalent to a 2-year recurrence storm day on the basis of a partial duration series. The actual number of years in which the 18 storm days occurred was 13. Three storm days occurred in 1948 and in 1925, and two in 1934. The specific dates of occurrence are given in Table 1. Nine of the 18 storm days occurred in July, the month when grain crops in Illinois are normally most susceptible to hail damage.

The time of occurrence and duration of the hailstorms on the 18 storm days also were investigated. On three of the 18 days, hailstorms occurred at two distinctly different times, separated by a period of two hours or more with no hail. Therefore, 21 periods of hail were analyzed as separate time events, and the time analyses were based on these 21 samples.

The 2-hour period when hail formation was most frequent was from 3:00 to 5:00 P.M. CST as 9 of the 21 hail periods were initiated in these two hours. Twenty of the hail periods began in the 11:00 A.M. to

TABLE 1.—Monetary losses and percent of annual farm value lost by damages produced by 18 most severe summer hailstorm days, 1915-50.

Rank	Storm date	Total storm loss, in thousands of dollars, normalized to 1910-14 price indices	% of total storm loss		Total storm crop loss as % of annual farm value
			Crop damages	Property damages	
1.....	8/17/48	3,173	99.8	0.2	0.26
2.....	7/28/43	2,719	88.0	12.0	0.31
3.....	7/22–23/31	665	99.8	0.2	0.38
4.....	7/10/34	1,152	43.5	56.5	0.20
5.....	6/20–21/15	399	85.1	14.9	0.08
6.....	7/13/34	351	98.8	1.2	0.14
7.....	8/18/25	351	100.0	0.0	0.08
8.....	7/1–2/33	273	100.0	0.0	0.13
9.....	6/14/48	503	95.0	5.0	0.04
10.....	8/29/48	478	100.0	0.0	0.04
11.....	8/18/46	410	97.6	2.4	0.03
12.....	8/9/25	265	100.0	0.0	0.06
13.....	7/24/25	255	98.8	1.2	0.06
14.....	8/9/32	134	82.2	17.8	0.06
15.....	7/10/30	112	97.2	2.8	0.04
16.....	7/25/38	118	76.8	23.2	0.03
17.....	6/25/44	214	80.9	19.1	0.02
18.....	7/21/27	116	97.3	2.7	0.03

11:00 P.M. CST period. Hail began at 4:00 A.M. CST in the one exception. The 6-hour period of most frequent hail initiation was 3:00 to 9:00 P.M. CST with 15 of the 21 hail periods beginning in this time period. Lemon (1943) reported that one-third of 2105 damaging hailstorms in the Middle West began in the 2-hour period after 4:00 P.M. CST. Lemon also found that 68% of 2105 damaging hailstorms in the Middle West began in the 6-hour period beginning at 1:00 P.M. CST.

The average duration of the hail periods was 2.4 hrs. and the median duration was 2.0 hrs. The greatest duration for one storm period was 6.5 hrs. and the shortest duration was 0.4 hrs. There was no correlation between variations in hailstorm duration and amount of damage produced by each storm.

Monetary Losses

Monetary losses produced by the eighteen storm days ranged from a high of $3,172,508 to a low of $112,472, as normalized by 1910-14 price indices. Three storm days each produced more than one million dollars in damage, and 13 had losses in excess of a quarter of a million dollars. The 18 storm days produced a total of $11,687,500 in losses for an average of $649,305. A summary of losses for each storm day, as presented in Table 1, shows that losses from crop damages accounted for a large proportion of

the total loss in most storms. On only one storm day did property damage exceed crop damage, and on four storm days no property losses were recorded.

The right-hand column in Table 1 lists for each storm day the percentage of annual farm value lost because of crop damages (Illinois Agricultural Statistics, 1949). This was the other major factor used in evaluating the storm days and in assigning rank values to them. A wide range exists in these values (Table 1), from 0.02% up to 0.38% with an average of 0.11 % per storm. These percentages appear to be small in relation to the Illinois farm value in any one year, but for a more realistic present-day impression, a percentage loss in 1954 such as suffered in the July 1931 storm would amount to $4,700,000 in 1954 dollars (Illinois Agricultural Statistics, 1958).

Maximum Hailstone Sizes

The maximum size of hailstones occurring in each of the 18 storm days was expressed in stone diameter. If stones were elliptical, the greatest diameter measurable for the stone was used in this analysis. On all storm days the maximum diameter found exceeded 1 in. The average diameter of the largest hailstones was 1.9 in. The largest hailstones found in any of the storms were 4 in. in diameter and these occurred in the June 1915 storm. In this storm, many cattle and hogs in the open fields were killed by the hail. Three of the other storm days had hailstone data also worthy of mention. The storm of June 14, 1948, produced hail 4 in. deep along a path 4 by 16 mi. with occasional drifts of hailstones up to 4 ft. deep. The storm of August 9, 1925, produced hail to a depth of 3 in. over a path 3 by 24 mi. During the July 10, 1934, storm, slabs of hail the size of coffee saucers were reported. In general, differences in the maximum size of the stones, in the range of 1 to 4 in. in diameter, had no apparent effect on the amount of damage produced by the storms.

Areal Distribution

Hailstorm path sizes. Complete data on all the hail paths which occurred in the 18 storm days were not available. However, sizes of many of the major paths were recorded as to width and length in miles. From the 18 storm days accurate path size data were available for 14 hail paths, and these 14 paths were associated with 15% of the total loss of the 18 storm days. Analysis of the path sizes indicated that the average width was 4 mi. with widths varying from 2 mi. to 10 mi. Lemon (1943) reported that the average path width for 2105 damaging hailstorms in the Middle West was 1.5 mi. The average length of the 14 paths was 18 mi; the shortest path was 8 mi. and the longest path length, 40 mi. The amount of loss associated with a path did not appear to be a function of path length or width.

Number of separate areas of hail in each storm. Areal analysis of the hail reports for the 18 storm days revealed that frequently two or more noncontiguous areas of hail occurred on a storm day. The basis used to define these separate areas

Fig. 1.—Forty U. S. weather stations with reliable hail records in 1915-50.

of hail on a storm date was a distance of at least 40 miles with no hail reports between hail areas. Using this basis, 12 of the storm days had two or more distinct hail areas and seven of these had three hail areas. This analysis indicated that 37 hail areas were produced by the 18 storm days. In general, the severest of the 18 storm days were the days with three or more hail areas.

Number of weather bureau stations reporting hail in each storm. On eight storm days hail was reported at four or more of the 40 U. S. Weather Bureau stations used in this analysis (Fig. 1). The greatest number of stations reporting hail on any one day was nine on August

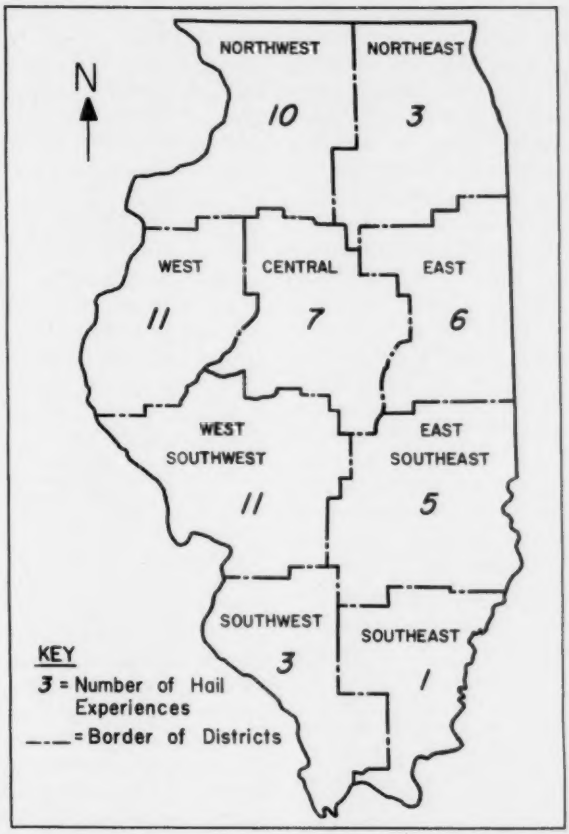


Fig. 2.—Number of times that each crop district was affected by the 18 most severe summer hailstorms.

17, 1948. On a monetary basis, this storm day was classified as the most severe of the 18. Flora (1956) in his listing of severe Illinois hail storms also classified this hailstorm day as the worst on record in Illinois, although his loss data were not normalized for changing prices. In general, there is a good relationship between the rank or severity of the storms and the number of Weather Bureau stations reporting hail.

Regional and county distributions of hail. From detailed areal plots of hail on each storm day, the number of times each county experienced hail was determined. Utilizing these data, the number of times these 18 storm days produced hail in each

U. S. Weather Bureau crop-reporting district (Illinois Agricultural Statistics, 1958) also was plotted. The areal frequency results for the nine Illinois crop-reporting districts, which are areas of approximately equal size, are shown in Figure 2. Since hailstorms during most of the 18 days affected more than one district, the total number of occurrences was 57, exceeding the number of storm days by a factor of three. Inspection of Figure 2 shows that the upper two-thirds of the western portion of Illinois had the greatest number of experiences with the three westernmost districts having almost equal frequencies. The number of occurrences by districts diminishes rapidly to the south and east from the high incidence region in the west.

To obtain a more detailed description of areal distribution, the number of times each county experienced hail resulting from the 18 storm days was plotted (Fig. 3). The pattern is similar to that in Figure 2, although the concentration in western Illinois separates, on the county basis, into two distinct areas of most frequent experience. The most prominent area, with four or more experiences, extends northeastward from Adams County for 200 miles into Carroll County. A secondary maximum occurs in three counties: Morgan, Sangamon, and Montgomery. Areas of no experience are shown in portions of northeastern, eastern, and southern Illinois. The general distribution pattern revealed by this map relates well to the average summer hail distribution in Illinois (Huff and Changnon, 1959).

To describe the county distribution of hail damage, the number of times each county experienced hail damage is shown in Figure 4. The pattern is generally similar to that in Figure 3 except that the areal frequency values are lower and the areas of high incidence are smaller. The entire southeastern half of Illinois except for a few isolated areas, had no hail damage. Three counties, Whiteside, Warren, and Hancock, had the greatest frequency of damaging hail experiences.

Synoptic Weather

The type of surface synoptic conditions associated with the occurrence of the 18 hailstorm days was investigated. No analysis of upper-air data was performed due to the lack of these data during most of the 36-year period of study. Analysis of surface weather conditions revealed that four different surface weather types were associated with the hailstorms on the eighteen days. As might be expected, squall lines were the most frequent type of weather associated with hailstorms, eight storm days having squall lines. The number of cold front cases was five with four cases being associated with warm fronts. One hailstorm day was associated with air mass conditions.

Associated Weather Conditions

Severe weather. All but four of the severe storm days had associated reports of high surface winds. Nine of these 14 storm days with high surface winds had wind damages in addition to the hail damages. The

storm of August 17, 1948, had a tornado in addition to high surface wind reports. In several of the storms, damages from lightning were reported. In most instances, these reports of wind and lightning damages were in the area of hail damage. The presence of high wind velocities serves to increase the damage potential from hail.

Rainfall. The daily rainfall pattern associated with each of the 18 storm days was plotted using U. S. Weather Bureau records (1915-51). From these maps, studies of the association of rainfall and hail were made by comparing the location of hail areas with respect to the cores in the daily rainfall pattern, by ascertaining mean daily rainfall values for the hail areas, and by determining the state-wide rank of the highest daily rainfall value found in the hail areas of each storm day.

To ascertain the juxtaposition of the hail area and the rainfall cores, the hail areas were described as being either in or out of a rainfall core. A rainfall core was defined as a region of relatively heavy rainfall having appreciable decreases in rainfall amounts away from the region in two or more directions. As mentioned previously, there were 37 separate areas of hail on the 18 hail days. Thirty-four of these hail areas were found to lie within rainfall cores which indicated that a relationship existed between areas of maximum rainfall and hail incidence areas. A previous study of the relationship of hail occurrences to rainfall cores based on severe spring hailstorm days in Illinois (Huff and Changnon, 1959) indicated that 63% of the hail occurrences were in rainfall cores as compared to 92% in these 18 summer hailstorm days.

To obtain an estimate of the areal significance of the heavy rainfall found within the hail areas, the highest point rainfall value occurring in a hail area for each storm was selected. This value then was compared with all point values in the area of Illinois with no hail occurrences, and the highest hail area value was assigned a rank in relation to all other high values in Illinois. This analysis revealed that, in 13 of the 18 storm days, the highest point rainfall in the hail area ranked either first or second for the entire state on those 13 storm days.

Conclusions

The 18 most severe summer hailstorm days in the 1915-50 period produced losses which appear large to the average Illinois citizen and farmer, but the actual amount of the Illinois annual farm value destroyed by the most severe hailstorm day was minor, only 0.38 percent of the total. The greatest amount of damage on one storm day, normalized to 1910-14 price indices, was $3,172,508, which occurred on August 17, 1948.

The hailstorms on the 18 days occurred most frequently in the late afternoon and early evening, and the duration of hail averaged 2.4 hrs. No correlation existed between storm duration and amount of monetary loss. Maximum hailstone sizes associated with the extremely severe summer hailstorms were at least 1 in. in diameter, although the amount

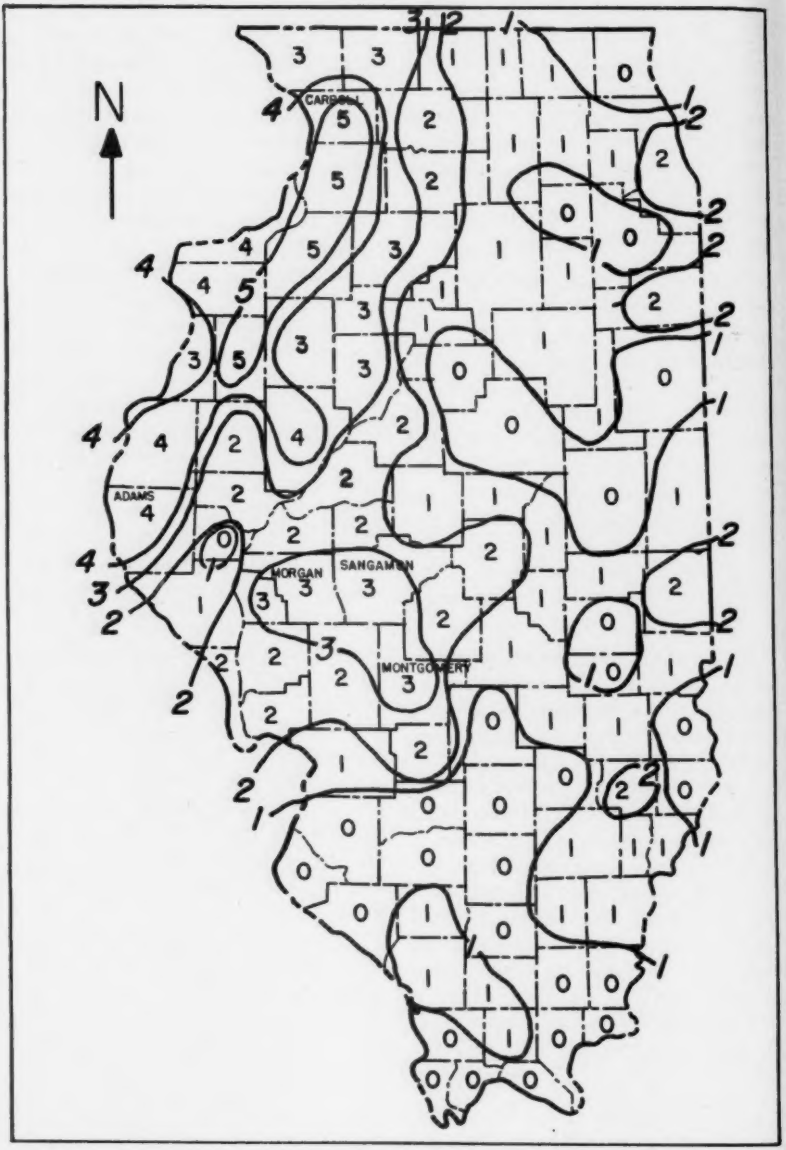


Fig. 3.—Number of times each county experienced hail produced by the 18 most severe storms.

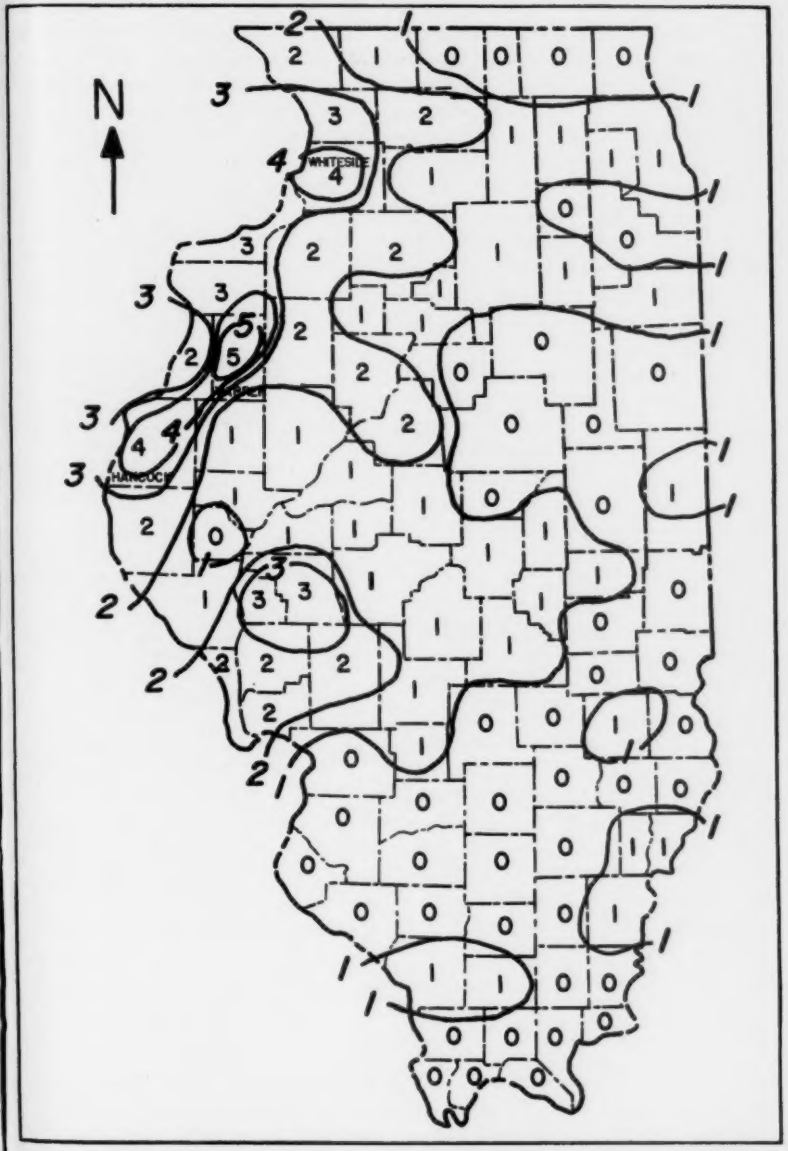


Fig. 4.—Number of times each county experienced hail damage resulting from the 18 most severe hailstorms.

of damage produced by a storm was not a function of maximum stone size, differences occurring in the range from one to four inches in diameter. Path sizes associated with the severe hailstorms varied considerably. The average path width was 4 mi. and the average length was 18 mi. There appeared to be no relation between the path size and the amount of damage produced.

Based on the 18 storm days studied, summer hailstorm damage was most frequent in western, northwestern, and southwestern Illinois, and was least frequent in southern Illinois. The areal extent of hail and hail damage varied considerably between storms, and occasionally the damage area was relatively small. However, normally the larger the area of hail, the greater was the damage. Therefore, areal extent of hail appears to be one of the best surface factors correlated with the amount of monetary loss.

The investigation of synoptic weather types associated with the severe summer hailstorms indicated that there was no single weather type which could be considered the predominating cause of these hailstorms. Most of the severe hailstorms were accompanied by high surface winds which increased crop damage from hail. The occurrence of high winds appears to be a second factor correlated well with the amount of damage. The areas of hail were frequently associated with heavy rainfall, often greater than 0.9 inch per day, and 92% of the hail areas were found in the rainfall cores. Frequently, the highest rainfall value in the hail area was the highest in Illinois for that date. However, the extent or intensity of rainfall did not always reflect the amount of hail damage.

Literature Cited

Anon. 1915-1951. Climatological data, Illinois, 1915-50. Washington, D. C., Government Printing Office.

Anon. 1949. Illinois agricultural statistics. Springfield, Illinois, Illinois Co-operative Crop Reporting Service Circular 445: 77-122.

Anon. 1958. Illinois agricultural statistics. Springfield, Illinois, Illinois Co-operative Crop Reporting Service Bulletin 58-2: 94-110.

Flora, S. D. 1956. Hailstorms of the United States. Norman, Oklahoma, University of Oklahoma Press, 195 pp.

Huff, F. A. and S. A. Changnon. 1959. Hail climatology of Illinois. Urbana, Illinois, Illinois State Water Survey Report of Investigation 38, 68 pp.

Lemon, H. 1943. Semimonthly distribution of hail in the United States. Monthly Weather Review, 71 (7): 115-122.

Stout, G. E., R. H. Blackmer, S. A. Changnon, and F. A. Huff. 1959. The hail hazard in Illinois. Urbana, Illinois, Illinois State Water Survey, 33 pp.

Manuscript received July 28, 1960.

STRATIGRAPHIC ASPECTS OF THE CASEYVILLE GROUP IN THE VICINITY OF POMONA, JACKSON COUNTY, ILLINOIS

GEORGE A. DESBOROUGH
Southern Illinois University, Carbondale

Introduction

The area studied in this investigation is situated along the margin of the Caseyville (basal Pennsylvanian) outcrop area in extreme southwestern Illinois (Fig. 1). In this report some stratigraphic aspects of the Caseyville rocks which are well exposed in the area and certain relationships of pre-Pennsylvanian channel development which have not been considered heretofore will be pointed out.

Part of the field work for this investigation was conducted between the fall of 1957 and the summer of 1958 as part of a mapping project in cooperation with the Illinois State Geological Survey. It is based on detailed field study and detailed geologic sections. The author is solely responsible for the opinions and conclusions expressed herein.

Stratigraphy and Structure

The study area is underlain dominantly by strata of Caseyville age

Fig. 1.—Index map of study area showing Wanless' channel.

TABLE 1.—Geologic column in Pomona and vicinity.

		FORMATIONS	Thickness in Feet	LITHOLOGY
PENNSYLVANIAN SYSTEM	CASEYVILLE GROUP	POUNDS SANDSTONE (LOWER MAKANDA)	90–130	Sandstone, massive, cross-bedded, locally contains quartz pebbles.
		DRURY SHALE AND SANDSTONE	80–120	Shale and sandstone; carbonaceous shale, fine-grained sandstone, shale-pebble conglomerates.
		BATTERY ROCK SANDSTONE (LICK CREEK)	90–110	Sandstone, massive, cross-bedded, locally contains quartz and chert pebbles.
		LUSK FORMATION (WAYSIDE SHALE AND SANDSTONE)	30–60	Sandstone and shale; thin-bedded and fine-grained sandstones, arenaceous shale.
		UNCONFORMITY		
MISSISSIPPIAN SYSTEM	UPPER CHESTER SERIES	KINKAID LIMESTONE	0–70	Limestone, massive, cherty, fossiliferous; locally absent.
		DEGONIA SANDSTONE	40–80	Sandstone, massive and thin-bedded.
		CLORE FORMATION	20–70	Shale and limestone; calcareous shale; dark, dense, limestone, fossiliferous.
		PALESTINE SANDSTONE	20–30	Sandstone, thin-bedded, fine-grained.
		MENARD LIMESTONE	60–100	Limestone and shale, interbedded, fossiliferous.

which consist of interbedded sandstone and shale and include those superjacent to Chester strata and below the top of the Pounds sandstone (Table I). All of the Caseyville units discussed in this report were recognized by Lamar (1925, pp. 83-84).

Although it is not the purpose of this paper to discuss the structure of the area, a brief summary of it is necessary because it locally complicates the stratigraphy and both must be interpreted simultaneously.

Faults (Fig. 2) of both pre-Pennsylvanian and post-Pennsylvanian ages are common in the area and are numerous in secs. 28 and 33, T. 10 S., R. 2 W. (for greater detail see Desborough, 1957). In these two sections the pre-Pennsylvanian faulting is very complex, with tilted pre-Pennsylvanian strata truncated by basal Pennsylvanian sediments at a

Fig. 2.—Geologic map of study area.

conspicuous angular unconformity that is not very irregular if post-Pennsylvanian faulting is disregarded. Post-Pennsylvanian faults may be more common than illustrated because the similarity of the Caseyville sediments makes it difficult to recognize faults in them.

The major fault which strikes N 40-60°W is important because it tends to obscure the thickness of the lower Caseyville and upper Chester sediments. This fault has recently been traced almost nine miles along its strike. The displacement is greatest northwest of Pomona where the Degonia sandstone on the south side of the fault lies adjacent to the Pounds sandstone on the north. The displacement decreases southeastward.

Certain inconsistencies in the apparent displacement along some of the faults are attributed to two movements along the same fault plane; one during pre-Pennsylvanian, the other during post-Pennsylvanian time. Evidence indicates that in some cases these two movements were in opposite directions (Desborough, 1957, p. 201).

Lusk Formation

This formation is represented by a sandstone which is the lowest Pennsylvanian formation in the area. It is the equivalent of Lamar's Wayside sandstone and shale (Lamar, 1925, p. 84). It rests unconformably upon the Kinkaid limestone where the latter has not been removed by post-Mississippian — pre-Pennsylvanian erosion. The unconformable relationship between the Lusk and the Kinkaid limestone is well exposed northeast of Pomona in the major stream in the SW¼ SE¼ sec. 21, T. 10 S., R. 2 W. The Lusk-Battery Rock sandstone contact is exposed in the road cut about one-tenth of a mile east of Pomona.

In this area the Lusk formation is typically a fine-grained, thin-bedded micaceous sandstone in which thin shale beds are locally developed. Although it is somewhat carbonaceous in character, no laterally persistent coal beds have been found. Massive beds of medium-grained, poorly sorted, conglomeratic sandstone less than 10 feet thick are found as lenses which are apparently local. One of these beds is exposed along the stream in the SW¼ SE¼ sec. 21, T. 10 S., R. 2 W. The cementing material of the Lusk sandstone consists primarily of authigenic quartz which gives the rock a quartzitic fracture. An argillaceous matrix is common and one thin bed of medium-grained sandstone has a calcareous matrix and contains interstitial pyrite in the form of subhedral crystals and massive disseminated pyrite. Color varies from white, pale yellow, brown, to gray on both outcrop and fresh fracture. Most of the thin beds contain well-sorted quartz grains, in contrast with the poorly-sorted massive beds. Ripple marks are common and the current type is dominant.

Plant fossils are replaced by marcasite or represented by impressions in the sandstone and are thus poorly preserved. They are most abundant along the stream in the NE¼ sec. 28, T. 10 S., R. 2 W.

The thickness of the Lusk sandstone varies slightly in the Pomona area due to the irregularity of the

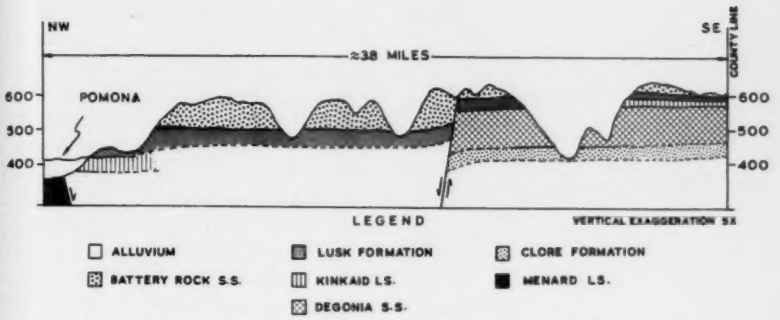


Fig. 3.—Cross-section from Pomona southeastward to the south side of sec. 36, T. 10 S., R. 2 W.

post-Mississippian — pre-Pennsylvanian erosion surface. The maximum thickness may exceed 60 feet. A good exposure of Lusk sandstone is found along the stream in the SW¼ SE¼ sec. 21, T. 10 S., R. 2 W.

In the stream bed of Topping Creek in the SW¼ SE¼ sec. 27, T. 10 S., R. 2 W., an arenaceous, ferruginous, limestone conglomerate is exposed. Due to slumping of the hillside, the thickness is undeterminable, but a bed one foot thick is exposed. The stratigraphic position of this unit is difficult to establish because a major fault (strike NW-SE) is situated a few hundred feet to the north of the exposure; however, stratigraphic relationships in the vicinity of the exposure indicate that the conglomerate is in the Lusk formation, perhaps the lower part. Large blocks of conglomeratic sandstone, similar to the Battery Rock, have slumped from the hill above and have come to rest near the limestone conglomerate.

The lithologic character of this limestone conglomerate is not like any rock-type recognized in the area. The matrix consists of arenaceous limestone, with subordinate crystalline limestone and calcareous, micaceous sandstone. The fragments are composed of dense limestone, ironstone and marcasite concretions, fine-grained, calcareous sandstone, chert pebbles, carbonized and silicified plant remains, coal, small quartz pebbles, and pale green discoidal clay inclusions, in order of abundance. The rock is well-cemented and resistant, and weathers with a knobby surface. Plant remains and one unidentifiable coral (solitary type) are the only fossils which have been recognized.

Excepting the chert and quartz pebbles in the conglomerate, the fragments are not appreciably rounded. Many of the larger fragments exceed three inches across and have an irregular shape. These characteristics imply that most of the heterogeneous rock was locally derived from pre-existing upper Chester strata. This conclusion is consistent with the findings of Siever

(1951, p. 548) who discussed a similar lithologic type.

Battery Rock Sandstone

This stratigraphic unit consists of medium-grained sandstone which is locally conglomeratic. It may be considered an orthoquartzite. Typically it is a massive, cross-bedded sandstone which forms prominent bluffs. It is the equivalent of Lamar's Lick Creek sandstone (1925, p. 85). A good exposure of the Battery Rock sandstone may be observed along the east valley-wall of Cave Creek north of Pomona where the resistant unit forms prominent cliffs and bluffs.

Both chert and quartz pebbles compose the conglomeratic elements of this sandstone. Along the base of the Battery Rock bluff about one-fifth of a mile northwest of Pomona, and east of the Gulf, Mobile and Ohio Railroad, chert pebbles as large as two inches in diameter have been found. This conglomeratic nature is not persistent, however, and for the most part the Battery Rock sandstone is not conglomeratic.

Cross-bedding and ripple marks are common features of the Battery Rock sandstone and the former feature is quite characteristic when contrasting this unit with the Drury sandstone above and the Lusk sandstone below.

Argillaceous material of primary origin is not common, although thin lenses of arenaceous shale were observed in the SW¼ sec. 21, T. 10 S., R. 2 W. Mica is generally rare and dark minerals are seldom conspicuous. Lithologically the Battery Rock sandstone is a clean quartzose sandstone in which secondary overgrowths are prominent in thin sections. Silica is the dominant cement but specimens obtained from most exposures contain secondary iron oxides as an interstitial component.

The Battery Rock sandstone is thought to have a maximum thickness of 110 feet in this area although no measurement has been made where stratigraphic relationships are clear. At Saltpeter Cave in the SW¼ NE¼ sec. 15, T. 10 S., R. 2W., the Battery Rock sandstone forms an overhang and here attains a thickness of about 90 feet.

Drury Formation

The Drury shale and sandstone, as described by Lamar (1925, pp. 91-95), lies stratigraphically above the Battery Rock sandstone and below the next persistent, thick, massive sandstone — the Pounds. Its variable lithology is perhaps the best criterion but the well-developed shale units and the fine-grained character of the sandstone also serve to distinguish the Drury formation from the massive Battery Rock and Pounds sandstones. Coal lenses are developed locally and plant fossils are abundant. The thickness of the Drury formation is thought to vary from 80 to 120 feet.

Correlation of individual sandstone or shale units within the Drury is difficult because they either are not persistent laterally or vary greatly in facies within short distances. Generally, described columnar sections less than one mile apart reveal no similarity.

A thin coal bed exposed about 10-15 feet below the Drury-Pounds

contact along the south valley-wall of Cedar Creek in S.½ sec. 10, T. 10 S., R. 2 W., has been correlated across Cedar Creek Valley to the north, but about two miles southeast, in the stream in the NE¼ NE¼ sec. 24, where the Drury formation and the Pounds sandstone lie apparently conformable, the coal bed is absent and in its stead there are several feet of dark gray, carbonaceous shale.

Pounds Sandstone

The Pounds sandstone is equivalent to Lamar's (1925, p. 95) lower massive Makanda sandstone. It is very similar to the Battery Rock sandstone with respect to its massiveness, cross-bedded nature, and the presence of quartz pebbles. One exposure in the C. sec. 13, T. 10 S., R. 2 W., consists of 126 feet of massive, cross-bedded sandstone which contains quartz pebbles. A similar section 128 feet thick is exposed in the NE¼ sec. 23. The Pounds sandstone forms persistent bluffs throughout the area due to its resistant nature.

Lithologically the Pounds sandstone is a clean orthoquartzite and for the most part is medium-grained, with secondary iron oxide cement. Plant fossil impressions are present. An exposure in sec. 13 contains a few thin lenses of shale.

Pre-Pennsylvanian Channels

During earlier studies Weller (1940, p. 23) thought that no greater than 250 feet of sediments represented the Caseyville group in the Alto Pass quadrangle (in which the present study area lies). It has been found in this investigation that at least 340 feet of strata lie between the top of the Pounds sandstone and the Mississippian-Pennsylvanian unconformity (Table I). The maximum compiled thickness of the individual units in this interval (Lusk formation through Pounds sandstone inclusive) is locally 420 feet. Previously Potter and Siever (1956, p. 228) thought that the maximum thickness of the Caseyville group in Illinois was about 400 feet and occurred in southeastern Illinois. Potter and Glass (1958, p. 12) give an average thickness of about 350 feet for the Caseyville group, which is somewhat less than the average in this area. The local maximum thickness of 420 feet for the Caseyville group is as great as in any other area in southern Illinois and on the assumption that the greatest thickness of clastic sediments would accumulate in the area of maximum subsidence supports Potter and Siever's concept of a southwestward regional slope during Caseyville sedimentation (1956, p. 240).

As projected by Wanless (1955, pp. 1760-61) and Potter *et al.* (1958, p. 1035), the major pre-Pennsylvanian channel which Siever (1951, p. 561) indicated as occurring near northeastern Jackson County and continuing southwestward across the county crosses the present study area (Fig. 1). Wanless (1955, pp. 1760-61) depicted this pre-Pennsylvanian channel as incised into undifferentiated Degonia, Clore, and Palestine while Potter *et al.* (1958, p. 1035) indicated that the Degonia is cut out of the channel in Williamson and Jackson Counties. If this is the case: (1) there should be no

Kinkaid limestone or Degonia sandstone in the channel area; (2) if the interfluve areas were capped by Kinkaid limestone while the channel base consisted of Clore or Palestine formations, there should be a local relief of 100 to 200 feet on the Pennsylvanian surface; (3) with such a local relief, there should be concomitant variations in the thickness and lithology of the basal Pennsylvanian sediments.

However, contrary to (1), the Kinkaid limestone has been recognized near Pomona and at a number of other exposures in the area (Weller and Ekblaw, 1940, pl. I) and may be as thick as 70 feet (Desborough, 1957, p. 200). Weller and Ekblaw (1940, pl. I) have also recognized the Degonia sandstone in large fault blocks along the G. M. & O. Railroad just south of Pomona and in relatively continuous outcrop three miles north of Alto Pass.

The thickness and lithology of the Lusk formation (basal Pennsylvanian) in sec. 27, T. 10 S., R. 2 W., in the middle of the supposed pre-Pennsylvanian channel, are no different from those in the exposures a few miles west of Pomona (C. sec. 19, T. 10 S., R. 2 W., and SW¼ SE¼ and C. sec. 25, T. 10 S., R. 3 W.) and in a good exposure about two and one-half miles south of Pomona (NE¼ SE¼ sec. 5, T. 11 S., R. 2 W.), both of which are outside the channel. The uniform thickness and lithology is interpreted to indicate that the Lusk formation was deposited on a relatively flat surface (Fig. 3).

The author agrees with Wanless (1955, p. 1765) that Caseyville strata may be found in contact with Chester strata as low as Palestine sandstone. However this need not be due exclusively to pre-Pennsylvanian channel erosion. It has been shown by St. Clair (1917), Ekblaw (1925), and Desborough (1957) that post-Chesteran — pre-Pennsylvanian faulting has played an important role in the vicinity of Alto Pass and Pomona. Based on stratigraphic relationships (Desborough, 1957, p. 203), some of the displacements along the faults in the Pomona area are known to be 100 feet. Such displacements together with contemporaneous and subsequent erosion could account for unconformable relationships between Chester strata and the overlying Caseyville rocks. It is therefore concluded that the unconformable relations of the Chester and Pennsylvanian strata do not demonstrate the presence of a pre-Pennsylvanian channel in the area but can be adequately explained by post-Chesteran — pre-Pennsylvanian faulting with accompanying or subsequent erosion to a relatively flat surface on which the basal Pennsylvanian sediments were deposited.

Summary

1. There is no evidence to substantiate the presence of a pre-Pennsylvanian channel incised into the Degonia, Clore and Palestine formations in the vicinity of Pomona.
2. Pre-Pennsylvanian channel development in the vicinity of Pomona is not necessarily responsible for the local absence of the Kinkaid limestone and the Degonia sandstone. The absence of these formations locally is prob-

ably due to pre-Pennsylvanian faulting and subsequent erosion and weathering which reduced the local relief produced by the faulting.

3. The lack of considerable thickness and lithologic variation of the Lusk formation indicates it was locally deposited on an erosion surface of low relief.

4. The local maximum thickness of 420 feet for the Caseyville group is as great as any thickness measured along the outcrop belt and therefore may support the concept of a southwestward regional slope during Caseyville sedimentation.

Acknowledgments

I wish to thank Dr. Stanley E. Harris Jr. for criticism of the manuscript and helpful suggestions concerning field study. I acknowledge those students of Southern Illinois University who aided in describing and measuring about 6000 feet of strata distributed among more than 30 detailed geologic sections.

I am indebted to the Illinois Geological Survey for financial aid and transportation expenses during part of this study.

I also wish to thank Mr. K. Dean McIlravy for preparation of the finished illustrations.

Literature Cited

Butts, Charles. 1925. Geology and mineral resources of the Equality-Shawneetown area. Ill. St. Geol. Surv., Bull. 47. 76 pp.

Desborough, George A. 1957. Faulting in the Pomona Area, Jackson County, Illinois. Trans. Ill. St. Acad. Sci., 50: 199-204.

Ekblaw, G. E. 1925. Post-Chester, pre-Pennsylvanian faulting in the Alto Pass Area. Trans. Ill. St. Acad. Sci., 18: 378-382.

Lamar, J. E. 1925. Geology and mineral resources of the Carbondale quadrangle. Ill. St. Geol. Surv., Bull. 48. 172 pp.

Potter, P. E., and H. D. Glass. 1958. Petrology and sedimentation of the Pennsylvanian sediments in southern Illinois. Ill. St. Geol. Surv., Rept. Invest. no. 204. 60 pp.

Potter, P. E., E. Nosow, N. M. Smith, D. H. Swann, and Frank H. Walker. 1958. Chester cross-bedding and sandstone trends in Illinois basin. Amer. Assoc. Petrol. Geol. Bull. 42: 1013-1046.

Potter, P. E., and R. Siever. 1956. Sources of basal Pennsylvanian sediments in the Eastern Interior basin, Part I. Cross-bedding. Jour. Geol., 64: 225-244.

Siever, R. 1951. The Mississippian-Pennsylvanian unconformity in southern Illinois. Amer. Assoc. Petrol. Geol. Bull. 35: 542-581.

St. Clair, Stuart. 1917. Oil investigations in parts of Williamson, Union and Jackson Counties. Ill. St. Geol. Surv., Bull. 35: 40-54.

Wanless, H. R. 1955. Pennsylvanian rocks of the Eastern Interior basin. Amer. Assoc. Petrol. Geol. Bull. 39: 1753-1820.

Weller, J. M., and G. E. Ekblaw. 1940. Preliminary geologic map of parts of the Alto Pass, Jonesboro, and Thebes quadrangles. Ill. St. Geol. Surv., Rept. Invest. no. 70. 26 pp.

Manuscript received July, 1959.

PROGRESSIVISM IN ILLINOIS COMMUNITIES AS MEASURED BY LIBRARY SERVICES

ROBERT W. JANES
University of Illinois, Urbana

Introduction

The aim of this study is to discover the population characteristics of those Illinois communities which can be regarded as "progressive". Towns and cities which express progressivism are marked by a pattern of community services and a use of municipal resources different from other localities in the state. The progressive type, as the term suggests, are those places which are first to adopt certain policies or programs which serve or benefit the whole community and which are regarded as desirable for all localities. At least, such programs and policies, in time, come to be accepted by other municipalities after the innovation has been made in various progressive communities. These places can be regarded as the "pace-setters" in introducing into localities items such as public streetlighting, the city-manager, the planning commission, the mental health clinic, school consolidation, local art and recreational programs, the traffic engineer, human relations commissions and other functions which are expected to provide over-all services for the local population. In short, progressivism betokens allocation of a higher proportion of municipal funds and of the budget of other local governmental units for purposes which benefit the residents-at-large. The question to be answered here is, is it possible to discover the characteristics of the people who live in progressive localities?

The underlying purpose for seeking an answer to this question is to build up a body of information about conditions and influences in the towns and cities of Illinois which affect their response to the expanding challenges offered to community life. It seems likely that the current public debate revolving about the desirability and feasibility of increasing the amount of community support for services to local inhabitants will continue. Some understanding of the nature of the localities which now impose upon themselves a high burden for such services may cast light on both the capacity and desire of other communities to follow this trend.

Method and Results

The first step was to select an index of progressivism. Such a measure would be one for which there was accurate report as to its presence and extent in various localities including smaller cities; it should be a service for which professional personnel were readily available so that any community which wished to avail itself of this function could do so at reasonable expense, and it should be a service which could vary in degree of adequacy where it is present. Library facilities and personnel appeared to satisfy these requisites, so the record of community library services was selected as the index. Communities with a high level of such services are assumed to be progressive.

The next step was to choose known characteristics which would describe the population composition of the communities of the state. Obviously, the volumes of the decennial U. S. Census of population offer the best set of pertinent and comparable data for this purpose. The Census reports eleven traits of population for all places over 2,500 in size. These traits could be statistically correlated with the information on library services available for all urban places. Then, population traits which showed a marked correlation with measures of a high level of library service would describe local populations which were progressive; those traits statistically associated with a low level of library services would indicate "non-progressive" localities; and, if a trait showed no relation with any of the library indices, it could be said to define a population make-up which was "neutral" to progressivism. The procedure followed was to correlate all population traits with all the items of information on library facilities reported for the communities of the state.

The sample of localities selected included all the places defined as urban in the U. S. Census of 1950 outside of the metropolitan area of Chicago, which was taken to include Cook, Dupage, Lake, Will and Kane counties. Towns and cities in the Chicago region were excluded because it was felt that the large number of commuter suburbs in the area represented a different class of communities in respect to expenditures for community services. The data on library facilities for the selected communities in the rest of the state were compiled from the September, 1951 issue of *Illinois Libraries*, and these variables are shown in Table 1. Community characteristics were items reported in the *United States Census*, 1950 for all urban places and are shown in Table 1. Item 2 in this table, population increase from 1940 to 1950, was computed separately for the nine communities whose 1950 population was reported in the *Education Directory* as containing students in excess of ten per cent of the population. This correction was necessary because the 1950 census was the first to report students as community residents.

The averages and standard deviations of the 154 communities in the sample for all twenty-six variables were figured with the results also shown in Table 1. In respect to most items in the table, there is a broad range in the values for the items. This might be expected when communities range in size from 2,500 to more than 100,000 population. As a group of traits the library variables show greater variation, as for example, the per cent of population registered at the library, the per capita circulation, hours open per week and the two primary criteria of progressivism in library service —tax income and tax expenditure per capita. The only community variable which shows such extreme variation is per cent engaged in manufacturing. Certain other community variables such as median age and median school year completed show a relatively low range in values. In general, however, the range in the whole set of variables is such that product moment inter-correlations between all 26 items would

TABLE 1.—Averages and standard deviations of 26 measures of community characteristics and library facilities of 154 Illinois communities over 2500 population as of 1950.

No.	Item	Arithmetic Means	Standard Deviations
	Community Variables		
1	Size	11000.000	1639.000
2	% population increase 1940-1950	15.866	2.373
3	Median age	33.271	3.531
4	% sixty-five years and older	11.290	3.079
5	% non-white	2.872	.964
6	Median school years completed	9.510	1.078
7	% male in the labor force	78.202	7.498
8	% female in the labor force	29.341	4.794
9	% engaged in manufacturing	27.621	14.896
10	Median income	2771.400	568.800
11	% income less than $2,000	34.234	11.114
	Library Variables		
12	% of population registered	37.850	19.230
13	Book stock, in volumes	20450.000	3180.000
14	Total circulation, yearly	49460.000	8415.000
15	Per capita circulation, yearly	4.026	2.073
16	% of the circulation that was fiction	68.110	18.842
17	Hours open per week	38.928	19.079
18	Full time staff members	2.558	.521
19	Tax rate	.043	.002
20	Tax income	11690.000	2804.000
21	Total income	12810.000	2951.000
22	Total expenditure	11990.000	2673.000
23	% of total expenditure for books, magazines, and binding	19.318	8.854
24	% of total expenditure for salaries	42.377	13.640
25	Tax income, per capita	.800	.442
26	Expenditure, per capita	.864	.435

show many relatively large standard errors of estimate. This point must be kept in mind in evaluating the results of factor analysis of this set of data since it is obvious that many of the inter-correlations from which the factors are derived are not precise.

Factor analysis was chosen as the technique to discover any possible association of measures of progressivism with characteristics of communities. The advantage of factor analysis over other techniques such as multiple regression is that it demonstrates the broadest dimensions of association among the whole set of variables. Factor analysis also reveals association between particular variables which either are not easily discernible or are suspected from a matrix of raw correlations. Finally, this technique is appropriate in a problem such as this one which is exploring an area in which there are only limited hypotheses as to possible associations among the variables involved.

The factors were derived through the programs of the Illiac computer of the University of Illinois. The matrix of inter-correlations was fac-

tored by a centroid rotation with fixed communalities, and these results were rotated to orthogonal simple structure by the so-called Quartimax program. Six factors were selected as representing the basic clusters of correlations among the variables. These factors, each with an identifying designation and the component variables which show a high loading (.35 or greater) on the factor are shown in Table 2. The per cent of total variance attributed to each factor is shown in Table 3.

Discussion

Examination of the factors shows that three of them, Factor C, "Occupation-Income", Factor D, "Population Age", and Factor F, "Rate of Community Growth", contain variables which are exclusively community characteristics and do not show high association with library variables. These three factors, therefore, are of interest because they show clustering of traits which could serve to distinguish the neutral type

Table 2.—Variables with high factor loadings in six community-library factors after rotation to orthogonal simple structure.

A. "Community Size"

Variable No.	Loading
1	.950
13	.963
14	.945
17	.525
18	.977
20	.980
21	.981
22	.982
25	.419

B. "Socio-Economic Class"

Variable No.	Loading
6	−.457
8	−.552
15	−.742
17	−.502
19	−.646
25	−.801
26	−.827

C. "Occupation-Income"

Variable No.	Loading
4	−.365
7	.588
9	.776
10	.926
11	−.922

D. "Population Age"

Variable No.	Loading
2	−.368
3	.918
4	.776

E. "Race"

Variable No.	Loading
5	.436
7	−.383
16	−.781
23	−.734
24	−.580

F. "Rate of Community Growth"

Variable No.	Loading
2	.589
5	−.487
6	.616

Table 3.—Per cent of total variance attributed to each factor.

A	28.12
B	13.39
C	17.13
D	7.07
E	5.08
F	5.26

of community in respect to community progressivism. The "Occupation-Income" factor indicates that in Illinois communities there is a high association of per cent of males in the labor force, the per cent engaged in manufacturing and median income and that this cluster of traits shows some negative association with per cent of population over sixty-five years of age. The factor "Population Age" shows that communities which did not show population increase from 1940-1950 had a large proportion of aged in 1950. The factor "Rate of Community Growth" shows that the communities with a relatively high rate of growth in this decade tended to be low in per cent non-white and high in the median years of completed schooling in 1950. This factoring of variables into these kinds of clusters reveals patterns already described in the literature on locality characteristics and in this sense, these findings about Illinois communities simply confirm that the Illinois pattern is a typical pattern. What is important is that none of these factors shows significant loadings on the library variables, so that it can be assumed that these factors describe Illinois towns and cities which are neutral in respect to progressivism.

The other three factors contain, however, both community and library variables and suggest characteristics of local populations which may have a direct relation to measures of progressivism. "Community Size" is such a factor. Here all the high factor loadings except population size itself are on items describing library service. Most of these variables, such as number of volumes, total annual circulation and total expenditures could be expected to have a direct relation to community size. One important trait, however, library tax income per local resident, shows itself to be part of this cluster. This item can be regarded as a clear indicator of allocation of local resources to community welfare, and its presence in this factor suggests that size and progressivism are associated.

The factor "Socio-Economic Class" is an interesting combination of traits which casts light on what might be an important component of progressivism. This factor indicates that where median school year is low and per cent of females in the labor force is small, library facilities are poor, the hours of service are low, the tax rate is low as is per capita library expenditure. A low educational level combined with below average female employment suggests lack of white collar occupations. Such a lack appears in marked association with lack of progressivism. The final factor "Race" shows that high proportion of non-whites is in a negative relation to the per cent of males in the labor force and in expenditures for books and salaries of library personnel. Such a low level of services betokens non-progressivism in communities. Incidentally, one variable important in this factor confirms observations by professional librarians about the library habits of one segment of the local populations. The high negative loading on one item, per cent of circulation that was fiction, implies that where there is a large non-white population, cir-

culation in fiction is low. Several librarians commented that this finding agrees with their experience that generally Negro clientele are interested in books in the do-it-yourself and self-help categories.

Summarizing the information shown in these six factors provides general descriptions of progressive, non-progressive and neutral towns and cities. These descriptions refer to the basic dimensions of Illinois communities that are related to the support of local community welfare, as it is measured by the quality of library service. Progressive local populations tend to be large, with white-collar employment and a low proportion of non-white. Non-progressive localities have the opposite traits. Neutral communities have high incomes and a large proportion of the work force in manufacturing; they show less than the average rate of population increase from 1940 to 1950 if a high proportion of people were aged; and they underwent a high rate of increase from 1940 to 1950 if there was a high level of schooling and a low ratio of non-white.

Community Examples

Actual towns and cities, of course, cannot be expected to show all the characteristics of the progressive, non-progressive and neutral populations since the community dimensions defining these types are based on orthogonal factors which means that each factor is relatively independent of the other. However, when the census characteristics of an Illinois municipality show that a factor describes its population, then generally the local library facilities are at the statistically predicted level. For example, Freeport, which is twice as large as the average community in the state, provides library tax income per capita almost twice the average for Illinois communities. Eldorado and West Frankfort are low in the scale of white collar employment and are correspondingly low in library services. Wood River, a community high in income and manufacturing employment, is close to the average in its library facilities. Jacksonville shows a very high median age, practically no population increase from 1940 to 1950, and about average library facilities. Madison, with an unusually high proportion of non-white population, falls below the average in library salary expenditures. This evidence from a few sample communities indicates that community characteristics selected by factor analysis can be used in the prediction of progressivism in actual communities.

Of course, the discovery of a discernible relation between census characteristics of community and its level of library services does not mean that there is a direct causal relationship between these traits. Rather, it should be apparent that a factor analysis, like any other statistical correlation, can only set the stage for explaining the causes of progressivism and non-progressivism in communities. The many activities involved in allocating financial resources for any form of local welfare, including the library, represent local policies and practices which themselves should be analyzed. The present findings simply suggest

certain pre-conditions which apparently enter into the development of local practices and which are ultimately reflected in the differences among Illinois localities in indices of community services.

Summary

Progressive communities were defined as those providing above average support for local services including library facilities. A statistical analysis was made of U. S. Census characteristics and measures of library service in 154 Illinois towns and cities. The sample included almost all places of 2,500 or more population, according to the 1950 Census, outside of the Chicago metropolitan area. The results of this analysis showed patterns of census-reported traits which are associated with qualities of library service regarded as an index of a progressive community.

The statistical technique of factor analysis by computer methods was used to determine the inter-correlations of the library traits and community variables. This technique reveals any clustering or patterning of the variables in the form of factors. A factor represents a common dimension which the component variables, at least statistically, appear to share in some degree. Such a statistic presents itself as an appropriate device for depicting presence or absence of progressivism.

Six factors were selected as a measure of the pattern of statistical association of the twenty-six variables. The factor "Community Size" was positively related to adequacy of library service and was taken as an index of community progressivism. A second factor was defined as representing "Social Class" and served to identify the non-progressive community. Another factor, "Race", was to some extent related to poorer library service. The factor "Occupation-Income" was not regarded as linked to library-service adequacy as was also the case with the factor "Population Age". The factor "Rate of Community Growth" was not significantly associated with library facilities. These last three factors were taken to demonstrate the traits of communities neutral in respect to progressivism.

Literature Cited

Anon. 1951. Library service. Illinois Libraries, 33: 301-333.

United States Census 1950. Vol II, Part 13, Table 11.

United States Office of Education. 1950. Education directory. Part 3, Higher education — Illinois, pp. 44-52.

Manuscript received May 1, 1960.

ITAPACÍ, BRAZIL: RAPID GROWTH OF A FRONTIER TOWN

ROBERT L. CARMIN
University of Illinois, Urbana

The town of Itapací, Goiás, located 125 miles northwest of the new federal capital of Brasília (Fig. 1), is the product of an advancing agricultural frontier. This paper analyzes Itapací's growth with respect to economic developments which have taken place in its region. Itapací was first studied in 1948 when I described the town on its site and its regional functions (Carmin, 1955). In July 1956, I reexamined Itapací as part of a larger study dealing with the Goiás agricultural frontier (Carmin, 1958).

European occupancy in southern Goiás has undergone two stages—the mining and grazing periods—and during the two times I studied Itapací the area was experiencing a third phase, the rise of commercial agriculture, an activity which dominates grazing in some sections but is only beginning to compete with it in others. With each stage of occupancy, new towns were born and many existing towns disappeared or changed their functions in order to survive.

The development and rapid growth of Itapací has been a response to the rise of commercial agriculture. A combination of many factors—including a rapidly growing national population with a resultant greater demand for farm products, a decrease in production from the impoverished soils of the long-settled areas, and a national focus of attention on southcentral Goiás as an area of promising agricultural value—all have given rise to a rapid increase in the acreage devoted to crops in Goiás. Much of Brazil's central plateau is covered by *cerrado* (savanna-like) vegetation, but some parts contain *mato*, a semideciduous forest cover. The settlers of the region generally consider the *mato* soils excellent for crops such as coffee, corn, upland rice, cotton, and beans, but feel that the *cerrado* soils must be restricted to pasture land or at best only be used for less exacting crops such as pineapples (Waibel, 1948, p. 550). Thus to greatly simplify the situation, places such as Itapací, which lie within a great forested area, the Mato Grosso de Goiás (Fig. 2), have in recent years attracted growing numbers of pioneers who clear the forest and plant crops. The extension of the Goiás Railroad to Anápolis in 1935 aided the movement of people and supplies into south Goiás and provided an outlet to markets nearer the coast.

Encouraged by these developments, two farmers, in September, 1934, settled on the banks of the Rio São Patricinho near the northern edge of the Mato Grosso de Goiás. Within two years other settlers came to the area and the two farmers platted a small clearing in the forest nearby, lots were sold and Itapací was born. The settlement grew rapidly; in 1939 it became a *distrito* (township) seat and in 1945 it was elevated to the political position of municipio seat—the equivalent of our county seat.

Fig. 1.—Location map.

Itapací became the political, commercial, and cultural center for the municipio at the expense of Pilar, a decadent gold mining town founded in 1741 during the mining period. Pilar, or Itacê as it is called today, is outside of the forested zone of promising soils, hence settlers searching for productive farm land did not focus on and revive this old town. Instead, Itapací, situated within the forest, attracted settlers. But Itapací's growth and new status in the municipio was closely tied to the regional economic developments considered below.

In 1941 the Brazilian government created an agricultural colony at Ceres (the Colônia Agrícola Nacional de Goiás), 90 miles north of Anápolis (Fig. 2). In effect, the establishment of a colony within the Mato Grosso de Goiás served as a federal stamp of approval on the forest-covered lands. In addition, improved transportation facilities in

the form of an all-weather highway to the Colônia from the railhead at Anápolis stimulated settlement around and beyond the Colônia. The road reached the Colônia in 1945 and at the time of my first field study of Itapací in 1948, the federal road had been completed through the Colônia and some 44 miles beyond it. Thus a combination of factors caused the forested lands to attract settlers and an improvement in transport facilities made settlement there feasible. However, inaccessibility was still a handicap to Itapací's growth in 1948 because the final section of the only road to the town was a very poor single-lane route that turned westward from the good federal road a few miles north of the Colônia (see dashed line, Fig. 2). This rutted, narrow road which bridged gullies by a few hewn logs usually restricted the speed of the bus and truck serving Itapací to 5 miles per hour when they made their semiweekly run from Anápolis (Fig. 3). During the dry season when the road was at its best these vehicles required about 10 hours of uncomfortable travel to make the 140 mile trip in 1948. Although the road to Itapací was poor, only oxcart and horse trails extended beyond the

Fig. 2.—Site map. The S shaped area is the Mato Grosso de Goiás, a semideciduous forest area. Ceres is the headquarters of a national agricultural colony. The dashed line (arrow) shows the first road to Itapací largely lying outside the forest zone. The towns of Nova Glória and Nova Ponte are located at G and P respectively.

town. It was truly the end of the road for automotive vehicles.

Figure 2 shows an important fact about Itapací's location. The town is located within but near the north edge of the Mato Grosso de Goiás. This situation made it possible for Itapací to develop in the first place and speeded up its early growth. Although federal funds built a good road beyond the agricultural colony, Itapací's site is 18 miles west of the point where the federal road emerges from the northern extremity of the forested zone. Thus, the incipient town started by the two farmers was isolated by heavy forest on the south and except for the fact that its site was not far from the easily penetrated *cerrado* vegetation area just to the north, it would not likely have been laid out when it was—or certainly its growth would have been delayed. The first road to Itapací largely went through *cerrado* areas or skirted the edges of the *mato*. Thus fewer and smaller trees were confronted and, in addition, because the *cerrado* vegetation tended to be on the uplands or upper slopes of valley sides, the road was located where surface drainage was good, and only a few crude bridges were required.

Roads of this nature were very poor, but little else could be provided because the tax income was meager due to the small population and high

Fig. 3.—Old road to Itapací, now unmaintained and little used. The vegetation is denser in this small valley than along most of the route which goes through savanna. The rude bridge of hewn logs imbedded and retained only by earth fill was typical of the first road to serve Itapací.

Fig. 4.—New road through forest midway between Nova Glória and Nova Ponte. View, about 14 miles south of Itapací, shows good surfaced, wide road in section where some forest remains.

percentage of undeveloped properties. Although poor, the road did provide Itapací with a degree of access to the railhead, and hardy souls with faith in the future of the community were attracted. This route was enough to start the town on its way, but with such an inferior road the town's growth would be limited and other areas with similar farm land but better accessibility would surpass it.

Itapací's first road suffered a second handicap—it was round-about. The direct route to the railhead lay through the dense forest which provided two obstacles to easy road-building, namely, large trees to be

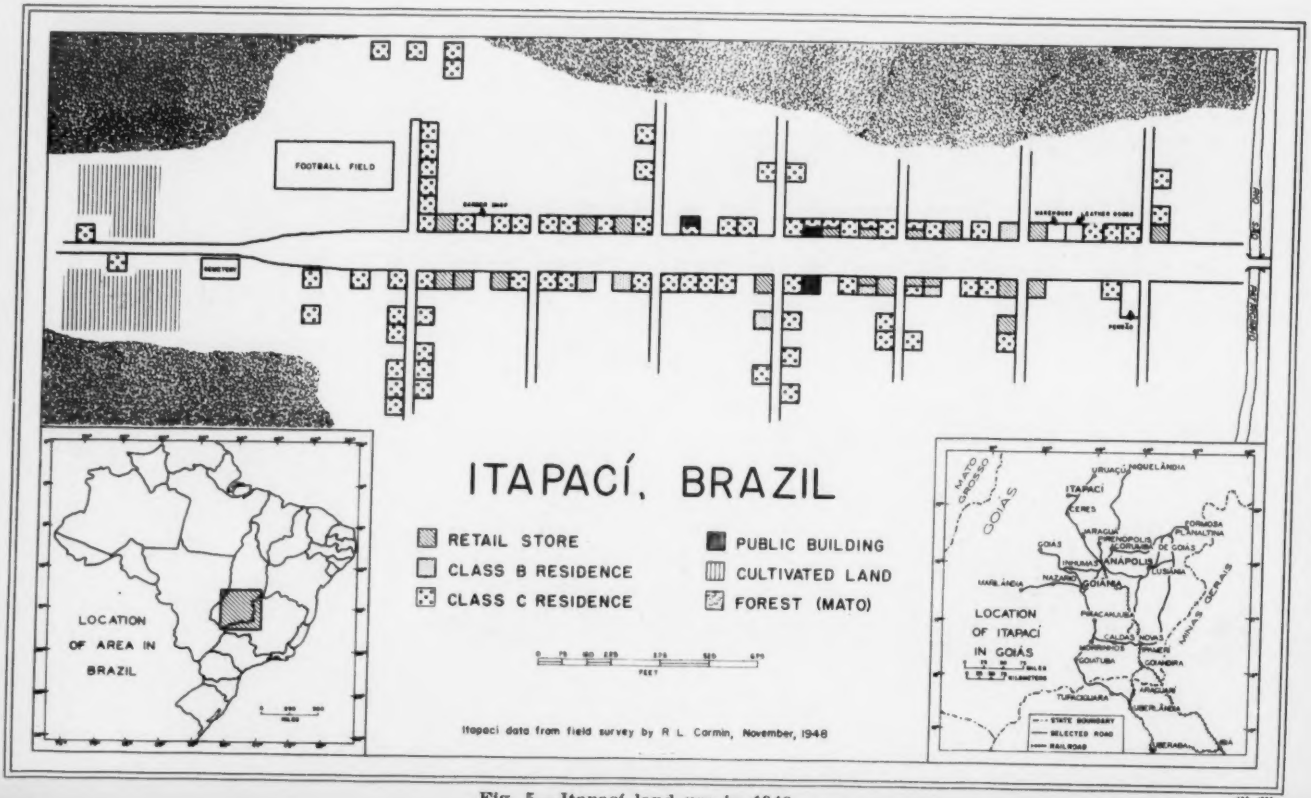


Fig. 5.—Itapací land use in 1948.

Fig. 5.—Itapací land use in 1948.

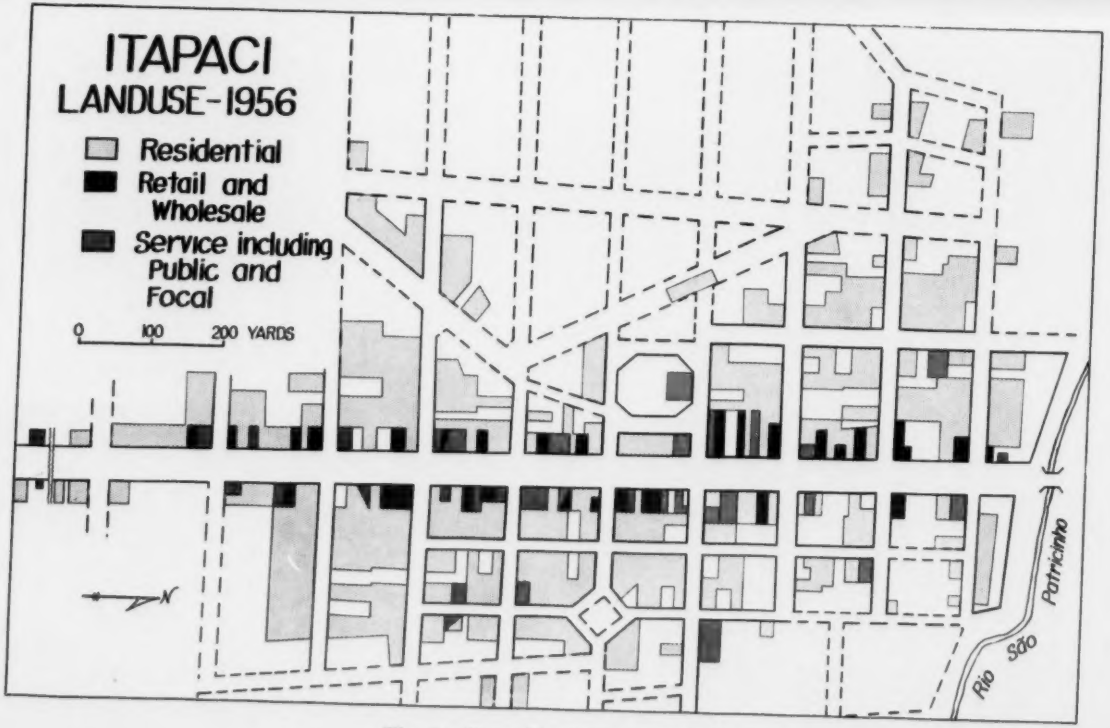


Fig. 6.—Itapací land use in 1956.

cut and destumped and numerous sizeable streams to be bridged. The meager population of Itapací Municipio in 1948, with about one person for each two square kilometers, could not afford the cost of building a road through the forest. Furthermore, the forest route would run largely through another municipio and be outside of Itapací's jurisdiction.

In time, however, the agricultural frontier advanced westward and northward from Ceres, the seat of the agricultural colony, along a more or less solid line through the reciprocal action of land occupance and transportational development. As people moved into the forest, first poor and then increasingly better roads were built to serve them (Fig. 4). By 1951 a road was extended from the federal road through the forest to the Rio São Patricio—just eight miles southeast of Itapací, and in October 1952, the São Patricio was bridged and this good road reached Itapací.

No longer was Itapací dangling at the end of a round-about, poor road — isolated from the relatively solid frontier of producing crop land. Nova Glória, a town of about 200 persons, soon developed at the road junction where the new road to Itapací turned off the federal road (G in Fig. 2). And spectacularly, the town of Nova Ponte, New Bridge, sprang to life where the São Patricio was spanned (see P, Fig. 2). Nova Ponte had a population of 800 to 1,000 persons in 1956 — just five years after the new road reached it. With the new road, Itapací is still on the outer fringe of urban settlement, but it is now near the front of the advancing line of agriculturally productive land in the Goiás frontier, and in a position to develop more completely by a sort of symbiotic association with nearby areas of settlement. With only the old, poor road, relatively few truckers, busses, or traveling salesmen bothered to go to Itapací unless for a special purpose because there were no towns for the whole distance of 54 miles between Ceres in the agricultural colony and Itapací. Moreover, very few farmers were to be found along the last 25 miles of this route because the *cerrado* areas supported few agriculturists. The new road, on the other hand, passes through two towns, many farms, and by numerous wayside stores where a variety of goods are traded or sold for agricultural produce from adjacent farms. In short, then, the presence of a relatively dense, productive population provides inducements such as bus customers, a market for goods, and a place where truckers can buy from wholesale collectors or the farmers. A trucker or salesman that goes beyond Ceres goes on to the next town, then the next, and so on—as long as the towns or farms are not spaced too far apart. The situation is similar to the clustering effect that occurs in shopping areas of large cities — each ready-to-wear clothing store stands to gain more in sales by being a part of an attractive nucleus than it loses by being in competition with other stores of its type in the area. With the new road, Itapací no longer dominates an underdeveloped area, but instead it is one of a cluster of towns all vying for a share of a growing, productive region. In time, one of the towns

Fig. 7.—View south along 120 feet wide main street of Itapací in 1956. New road enters town at far end of main street. Arrow shows rickety bridge (see Fig. 6), entrance-way in past via old road seen at left of arrow. Some virgin forest remains in right background.

in the cluster may, through propitious circumstances, outstrip the others in growth and, once a strong lead is taken, tend to restrict the growth of other nearby towns. It is yet too early to tell whether Itapací will be the favored one, but its early lead and its function as municipio seat give it strong advantages.

What has been Itapací's rate of growth? During the first fifteen years the town accumulated a population of approximately 900 persons. In the next six years, from 1949 to 1954, it doubled its population and in July, 1956, 2,075 persons resided there.[1] Figures 5 and 6 show land use maps of Itapací in 1948 and in 1956. Space does not permit us to examine in detail the spread of the town on its site or to consider the town's function as reflected in the kind and nature of its urban forms, but an examination of the two land use maps shows much concerning the growth of the town. The forest has been cut back, more streets have been laid out, and many more buildings have been constructed. Retail stores and a variety of services focus on the main street. The broken lines shown on the 1956 map are the original plat lines and they show the planned nature of the layout. Occupance of

[1] Data obtained from interview with Filomeno Luiz Fransa, Statistical Agent for the Instituto Brasileiro de Estatístico, Itapací Municipio, July 27, 1956.

the site has closely conformed to this layout with but one or two exceptions.

In 1948 Itapací Municipio was underdeveloped considering the proportion of land utilized for crops, and in agricultural productivity per person (Carmin, 1955, p. 116). Evidence indicated that a high proportion of the farms were too new to provide much more than subsistence living for their owners, that is, the farmers had not been on the land long enough to clear sufficient space for producing a surplus beyond their own needs. Today this situation is improved and it is significant that a commercial product, coffee, was harvested from 1,316 hectares in 1955.[2] Thus to a degree, the Municipio has overcome the space-time limitations on its growth. Enough time has now elapsed and more land is in crops, both subsistence and commercial. Also the new road has helped overcome much of the "space" or location handicap Itapací formerly suffered. In 1947 the Municipio had only .0004 of its area in crops. In 1952 the amount was .004, and in 1955 it had increased to .013.

Itapací is still a primitive place with few comforts, but there are many indications that the town will grow steadily in an orderly fashion in response to the development of its immediate vicinal area (the municipio), and of the larger, agriculturally productive area of which it is a part. With Brasília, the new federal capital, established in an area of relatively unproductive *cerrado* lands some 125 miles southeast, Itapací and the whole region in which Itapací is situated has a prosperous future ahead as a supplier of a rapidly growing urban market.

Literatue Cited

Carmin, R. L. 1955. Itapací, Brazil—a frontier town. Trans. Ill. Acad. Sci., 47: 111-116.

———. 1958. Roads and the advance of settlement on the Goiás Frontier of Brazil. Field research sponsored by Civilian Expeditions Program, Office of Quartermaster General and the University of Illinois Research Board. Mimeographed, 90 pp.

Waibel, Leo. 1948. Vegetation and land use in the Planalto Central of Brazil. Geog. Rev. 38: 529-554.

Manuscript received May 19, 1960.

[2] Agricultural production data from records of Secção de Estatística Militár do Departamento Estadual de Estatística, Goiânia, Goiás, provided by Maria du Glória Fleury, Aug. 10, 1956.

Editor's Note. A change of position and of locality has prematurely brought an end to my privilege of serving the Academy as Editor. I should like to thank the members of the Editorial Board and others who have helped with the evaluation and improvement of manuscripts. I am grateful to the authors for their cooperation and understanding and hope that this encouragement will be extended to the new editor, Dr. Wesley J. Birge, Department of Zoology, University of Illinois, Urbana.

P. C. Silva

PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy, not the carbon copy, is to be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Introduction*, *Acknowledgments*, *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, and *Literature Cited*. All papers should have a summary.

No footnotes are to be used.

The section entitled *Literature Cited* must include all references mentioned in text. It is not to include any other titles. No references to the literature are to be placed in footnotes. Citations under *Literature Cited* are as shown below:

Doe, John H. 1951. The life cycle of a land snail. Conchol., 26(3): 21-32, 2 tables, 3 figs.

Doe, John H. 1951. Mineralogy of Lower Tertiary deposits. New York, McGraw-Hill Book Co., iv + 396 pp.

Quoted passages, titles, and citations must be checked and rechecked for accuracy. Citations to particular pages in text are Doe (1908, p. 21) or (Doe, 1908, p. 21); general citation in text is Doe (1908) or (Doe, 1908).

Tabular information should be kept at a minimum. Tables should not be more than one page in length. Do not duplicate tabular data in text. Headings for tables and columns should be brief. Reduce to the barest essentials, or preferably omit, explanatory notes on tables. Each table and its heading should be on a single page; do not place any table on the same page with text.

Photographs should be hard, glossy prints of good contrast. Graphs, maps and other figures reproduce best when prepared for at least one-half reduction; lettering, numerals, etc. on all figures in a manuscript should be worked out to proper size for such reduction. Line widths, letter size etc. should be uniform from figure to figure within a published paper. Figures should be drawn on good quality white paper or on drawing board. Use only India ink. Use a lettering device (Leroy or Wrico) for numerals and words; do not print "free-hand."

Legends for photographs and figures should be brief; type them on a separate sheet of paper. Indicate figure number and your name on back of illustration; do not write with pencil on the backs of photographs.

Authors will receive galley proofs; these should be read carefully and checked against the original manuscript. Reprints may be ordered at the time galley proofs are returned to the Editor.

PAUL C. SILVA,
Department of Botany,
University of Illinois,
Urbana, Illinois.

ILLINOIS
Land of Lincoln